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NING AND DELINEATION OF SPECIAL USAGE LANES

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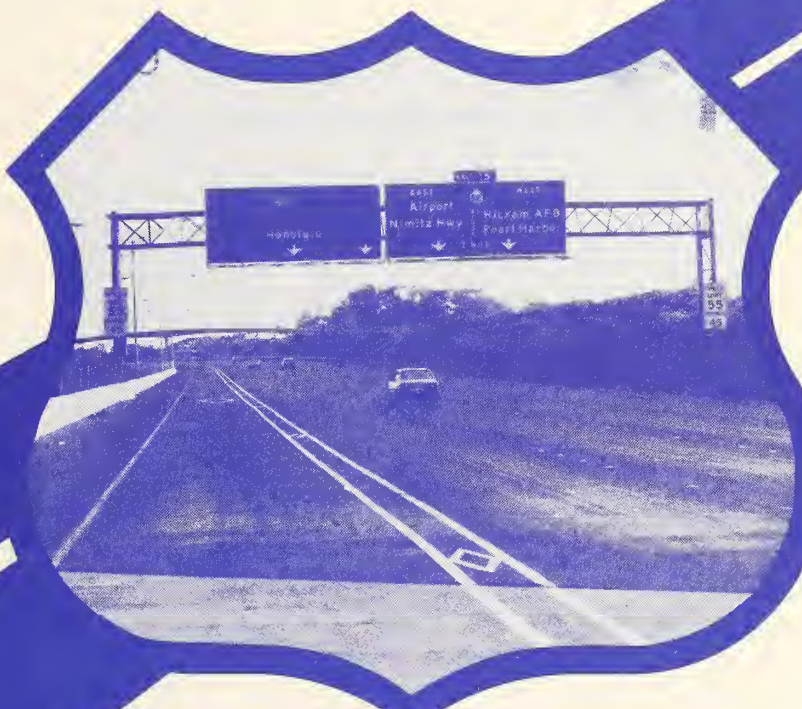
Vol. 3. Field Experiments and Implementation Suggestions

January 1982

Final Report



Prepared for

U.S. Department of Transportation

Federal Highway Administration

Offices of Research & Development
Traffic Systems Division
Washington, D.C. 20590

Document is available to the U.S. public through the National Technical Information Service Springfield, Virginia 22161

FOREWORD

This report is one of a series of reports resulting from the study, "Signing and Delineation for Special Usage Lanes." The report will be of interest to enforcement officials and to transportation engineers who are considering the implementation of special lanes for buses and carpools.

The research resulted in recommendations for signing and delineation systems for nine different classes of special use lanes. For each class, the information requirements together with the signing/marking mechanisms are presented in sufficient detail to permit their adaption to specific sites while at the same time ensuring a degree of standardization.

This volume documents the field evaluations and details the nine recommended information system configurations.

One copy of this report is being sent to each FHWA regional office, FHWA division, and State highway agency. The division and State copies are being sent directly to the division office.

Stanley R. Byrne

for Charles F. Scheffey
Director, Office of Research

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TE
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no.
FHWA-
RD-
81-064

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/RD-81/064		

4. Title and Subtitle	5. Report Date
Signing and Delineation of Special Usage Lanes Volume 3: Field Experiments and Implementation Suggestions	January 1982
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s) Richard F. Pain, Beverly G. Knapp, and Fred R. Hanscom	
9. Performing Organization Name and Address BioTechnology, Inc. 3027 Rosemary Lane Falls Church, Virginia 22042	10. Work Unit No. (TRAIS) FCP 32K4-012
	11. Contract or Grant No. DOT-FH-11-9291
12. Sponsoring Agency Name and Address Department of Transportation Federal Highway Administration, HRS-31 Washington, D.C. 20590	13. Type of Report and Period Covered Final Report July 1977 - September 1980
	14. Sponsoring Agency Code T-0447

DEPARTMENT OF TRANSPORTATION
SEP 0 1982
LIBRARY

15. Supplementary Notes

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16. Abstract

Special usage lanes (SULs) are those roadway lanes dedicated to particular vehicle types or to unique operating characteristics. The most common usage is for high occupancy vehicles (HOVs-buses and carpools). In this report SULs and HOV lanes are used interchangably and denote the same concept.

The energy shortages of the 1970's brought a proliferation in the number of SULs and considerable variation in the signing and delineation of these lanes could be found among regions, among cities and even within metropolitan areas. Recognizing the need for more uniformity in signing and marking systems, this research had as its objectives:

- o Determination of the information requirements of users and non-users of SULs.
- o Development of signing and delineation systems to meet the information requirements.
- o Evaluation of the efficiency of the developed signing and delineation systems.

The objectives were achieved through literature search, analyses of SULs across the country and development of initial SUL information systems. The systems were evaluated through 13 laboratory and closed field experiments. The laboratory findings and several SUL information systems were then verified through operational field studies.

This volume, the third in the series, describes the six operational evaluations that were conducted at seven east and west coast cities and includes design suggestions for information systems for nine classes of SULs. The others in the series are:

Volume No.	FHWA No.	Short Title
1	FHWA/RD-81/062	Executive Summary
2	FHWA/RD-81/063	Development of Signing and Delineation Alternatives

17. Key Words	18. Distribution Statement
Signing Delineation Special usage lanes HOV lanes Restricted lanes	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	202	

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CHAPTER 1
INTRODUCTION

Phase II of the project "Signing and Delineation for Special Usage Lanes" was a field test of various information presentation treatments found through information analyses and laboratory experimentation to be most promising in terms of:

- Standardizing signing and delineation methods used on special usage lanes (SULs) around the country
- Providing the information required by drivers encountering SULs
- Minimizing violation of SUL rules of use
- Clarifying message and meaning, conspicuity, and other sign/marking design factors.

Selection of Special Usage Lanes Treatments for Field Study

The determination of which signing/marking treatments should be tested, and where, was based on information from three sources. The first source was the SUL information requirements analysis. In that analysis a SUL classification scheme was identified with nine cells (see Figure 1). Each cell represents an SUL type with information requirements different enough from other SUL categories to warrant a separate cell. A second source of guidance was the laboratory studies reported in Volume II. This was the major source of data used in selecting treatments to be field tested. Finally, a considerable amount of discussion took place with FHWA staff members; their concerns, needs, and judgments were an important resource.

	Freeway		Arterial	
	Reserved	Non-Reserved	Reserved	Non-Reserved
Non Reversible	I-95-Miami* **7** 1 NPS	6	Bus Lanes **39** 11 NPS	16
Reversible	Shirley / Kennedy Expressway **3** 2 PS	7	Honolulu, Hawaii **1** 12 NPS	Reversible Lanes **14+** 17 NPS
Contra-Flow	U.S. 101, L.I.E. **3** 3 NPS	8	Market Street-Harrisburg **11** 13	18
Shoulder	BQE, Seattle-520 **2** 4 NPS	9	Seattle 522 **1** 14	19

PS = Physically Separated.

NPS = Not Physically Separated.

* = At least one example or descriptor is listed for each cell.

Figure 1. Special usage lane categories requiring signing and delineation system development.

A set of five decision criteria was established using the three sources of guidance just noted. Each SUL type and the signing or marking treatments for each SUL type were then reviewed in terms of these criteria.

1. Scope of Study. The contractual statement of work says that this contract ". . . shall be limited to reversible and reserved traffic lanes." Although non-reserved lanes were included in the categorization scheme and information analysis to assure completeness, they are not candidates for field testing. The importance of both arterial and freeway SULS was also evident from the statement of work.

2. Previous Laboratory Studies. This criteria stems from the desire to enhance the generalizability of the laboratory work and the overall validity of the research project. The implications of each of the studies reported in Volume II are summarized below.

   - Study 1, Chapter 5 evaluated a variety of symbols to inform drivers of SUL regulations. The main conclusions were that symbols should depict a front view of HOVs (buses, cars, taxis) and that numbers rather than graphics, e.g., riders' heads, should convey carpool ridership requirements. These findings could be confirmed by inclusion of reserved bus/carpool lanes and by varying the signing displayed.
   - Study 2, Chapter 5 examined drivers' interpretations of specific terms such as "reserved" and "restricted," used to describe SULs. Since interpretation was studied, and not a more overt behavior, field experimentation would add little to these results.

- Study 3, Chapter 5 looked at new sign concepts to meet advance and entrance information requirements for contra-flow and reversible lane SULs. The study suggested that arterial contra-flow lane signing would be useful, and a proposed type of sign needed field validation.

- Study 4, Chapter 5 dealt with information loading and spreading and sign formats. The results of this study clearly suggested that a standard word format be used on SUL signing. Results for information density and presentation techniques (single sign, repeated sign, information split between two signs) were less definitive. The problem of high information density on small signs along arterial SULs, particularly part-time reserved lanes, suggested that this issue be clarified through field study.

- Studies of Delineation, Chapter 6 concentrated on determining the design characteristics for SUL buffer zone treatments. The laboratory and controlled field studies suggest the hypothesis that a 1- to 2-feet wide buffer zone may deter SUL violations. This hypothesis can only be tested in a field setting and lends itself to both freeway and arterial application.

3. FHWA Concerns. The interests of FHWA, given its plans for future SUL implementation, were a major factor in determining the field studies. The expressed interest in buffer zones, specifically for possible application on urban interstate reserved bus/carpool lanes projects, suggested that primary emphasis be placed on freeway sites, with secondary emphasis on arterial settings.

4. SUL Frequency. Another criterion was real-world occurrence of each SUL category. Figure 1 shows that 49% of the inventoried sites fall into Cells #11 and #12--the reserved arterial bus lanes. Similarily, 13% are arterial contra-flow lanes, and 8% are freeway non-reversible bus/carpool lanes. Reversible lanes (Cells #2 and #17) also account for a sizable percentage of the SULs, but considering the other decision criteria there was little to field validate. A more detailed discussion of frequency and other reasons for not using the remaining SUL categories are given in Appendix A.

5. Current versus Experimental Signing. The final criterion revolves around the existing experience with a sign or marking. Signs that were created to fill an information void identified in this project and studied in the laboratory have a greater need to be field tested than signs already operating successfully in SULs.

Table 1 presents each of the criteria and the effect or outcome it had in establishing priorities for the field experiments. Using the priorities stemming from this analysis, five types of field studies were identified.

1. Compare all-word versus optional laboratory symbol configurations for carpools in a real-world setting.
2. Study the signing and buffer zone delineation on a freeway reserved bus/carpool SUL.
3. Examine signing and buffer zone delineation on an arterial reserved bus/carpool SUL.
4. Validate the effectiveness of signs for drivers crossing arterial contra-flow lanes.

Table 1

Criteria for Prioritization of SULs for Field Study

Decision Criterion	Effect
1. Scope of study	Eliminate non-reserved lane sites. Include both urban arterials and freeways.
2. Findings from previous tasks	
Task 2	
Study 1: Symbol Evaluation	Include carpool and bus usage lanes.
Study 2: Lane Definition	Not applicable.
Study 3: Sign Evaluation	Include arterial contra-flow lane.
Study 4: Information Formating	Include site to test information chunking.
Task 3	
Buffer zone design determination	Select location that supports buffer zone usage.
3. FHWA concerns	Emphasize buffer zone evaluation.
4. Real-world SUL representation	Include arterial, non-reversible right lanes; arterial, contra-flow lanes; freeway, non-reversible left lanes.
5. Current practice vs. suggested (from task analysis) signing/ marking practices	Field test untried or potentially controversial, i.e., substantially different from current MUTCD standard, treatments.

5. Clarify the role of different information presentation techniques (single sign, repeated signs, split or chunked signs) for high information load arterial situations.

Once the types of field studies were identified, suitable sites had to be located that could support real-world experimentation.

Selection of Sites for the Field Studies

The five studies require use of sites in three of the SUL categories:

- Carpool Symbol Study: Cell #1
- Signing and Buffer Zone Studies: Cells #1 and #11
- Contra-flow Signing Study: Cell #13
- Information Presentation Study: Cell #11.

The inventory for each of these cells was reexamined and the cognizant traffic engineers for each facility were contacted. From these initial contacts a list of candidate sites was prepared. Each site was visited and a detailed inspection of the facility and discussions with appropriate authorities took place. Final selections were made by comparing the site characteristics against a set of selection criteria.

Within cells several selection criteria were applied to the various sites. First, some type of control site was desirable. A sister facility was considered best, but another part of the same facility would suffice. Where control sites were available, a second geographic location (east vs. west) was desirable. If control sites were not available the geographic replication was essential.

Since time lapse data had to be collected, sufficient vantage points were important. Operational conditions had to be such that some observable behavior occurred that might be modified by signing/marking changes. If there was no violation of an SUL, weaving at the entrance to or along the facility, or other relevant behavior, the site could not support an evaluation.

Agency cooperation was imperative in that sign and marking fabrication and installation could be done only on a small scale with project resources. Larger efforts necessitated help from local agencies, and each locality had to be willing to allow treatments to be installed. Weather was considered, so that northern cities could be scheduled before snow. Unusual driver population shifts were considered. Finally, field data collection personnel availability and travel costs were a concern. Site selection proceeded within the bounds of these criteria.

SUL facilities were available at the completion of the site selection process to support each of the studies. These were:

- Arterial Bus Lane Signing and Buffer Zone Study:
  - State Street in Rochester, N.Y., was the east coast site. A sister site was not available, so a section of the same street served as the control site.
  - San Francisco was the west coast site for an arterial bus lane study. Two 1-way pairs, Post/Sutter and Geary/O'Farrell Streets, formed experimental and control sites.
- Freeway Bus/Carpool Lane Buffer Zone Study: The only sites that could be used for this study were the H-1 and Moanaloa Freeways leading into Honolulu. They were experimental and control sites, respectively.

- Information Presentation Study: Three streets with part-time concurrent flow bus lanes in Baltimore, Maryland--Calvert, Charles, and Fayette--were used. Calvert Street was the control; different signing treatments were placed on the other two streets.
- Carpool Symbol Study: Seattle's Pine Street ramp (over 1 mile long) with reserved bus/carpool lanes was the experimental facility; Cherry Street ramp served as a control site.
- Arterial Contra-flow Lane Signing Study: Since control sites were not available, two studies at different locations were considered imperative. The Market Street contra-flow lane in Harrisburg, Pennsylvania, and 5th Street at Jefferson Street in Seattle, Washington, were chosen.

Field Study Overview

Each study will be described in considerable detail in the following chapters. To place the individual studies in perspective, Table 2 presents an overall picture of the field studies. The studies are summarized as to treatments, measures of effectiveness (MOEs), and data collection techniques used. There are a number of MOEs and data collection techniques in Table 2 that are common to studies one through five. The types of comparisons or issues which can be addressed from these six studies are listed in Table 3.

Each study is described separately because there are treatment and data collection differences due to site conditions that must be noted. The Rochester study is described first because it incorporates all the elements of the next four studies. Therefore,

Table 2

Summary of the Field Studies

Study #	Treatment	Facility	Primary Measures	Data Collection Technique
1	Arterial Bus Lane, East Coast Upgrade below standard overhead signing to BTI recommended signs. Change from solid white line to buffer zone delineation.	Arterial Bus Lane, Rochester, NY: 6 blocks of State St. (experimental); northern portion of State St. (control)	Violation rate and type; weaving; driver awareness	Time-lapse film; interview
2	Arterial Bus Lane, West Coast Upgrade MUTCD standard side-mounted signing to overhead. Change from solid line to buffer zone delineation.	Arterial Bus Lane, San Francisco: Sutter/Post Sts. (experimental); Geary/O'Farrell Sts. (control)	Violation rate and type; weaving; driver awareness; bus delay	Time-lapse film; interview; bus timing (provided by city)
3	Freeway Buffer Zone Add buffer zone to otherwise complete information system.	Freeway Bus/Carpool Lane, Honolulu, HI: Moanaloa Freeway (experimental); H-1 (control)	Violation rate; weaving/ conflicts; delay; volume	Time-lapse film; manual counts
4	Information Presentation Upgrade signs; add diamonds. Present information as repeated signs and split	Arterial Bus Lanes, Baltimore: Fayette and Charles Sts. (experimental); Calvert St. (control)	Violation rate; weaving; delay/volume; driver awareness; driver understanding	Time-lapse film, manual counts, and timing; interview; in-depth drive-through and interview
5	Carpool Symbol Study Change existing signs from verbal to carpool symbol.	Bus/Carpool Ramp, Seattle, WA: Pine St. (experimental); Cherry St. (control)	Violation rate; volume; driver awareness	Manual counts; interview
6	Arterial Contra-flow Lane Signs Install signs to promote driver and pedestrian looking (at the contra-flow lane) behavior from cross streets.	Contra-flow Lane, Harrisburg, PA: Market and Court intersection; Seattle, WA: 5th and Jefferson Streets intersection	Driver and pedestrian head movement; bus volume	Time-lapse film; manual coding

Table 3

Issues Addressed by the Field Studies

- Effect of buffer zone delineation in freeway and arterial settings.
- The solid line and skip line diamond buffer zones compared.
- Test of buffer zone impact before signing changes are made on east and west coast--arterial bus lanes.
- Comparison of minimal overhead signs with recommended overhead signs. This will also be a systems test in that all new signing and buffer zones will be tested--arterial bus lane.
- Comparison of MUTCD standard shoulder-mounted with overhead signing--arterial bus lane.
- A freeway information system test--the existing signing is complete (including carpool symbols), and addition of the buffer zone results in a total information package.
- Comparison of minimal-level, shoulder-mounted signing with upgraded repeated signing plus pavement diamonds, and split or chunked signing plus pavement diamonds.
- Comparison of carpool symbols with word-only signs. This is a system test in miniature in that it is a self-contained SUL on a ramp.
- Cross street signing for contra-flow lanes tested on the east and west coast--arterial bus lanes.

the methodology is discussed in considerable detail in Study 1 and referenced in Studies 2 to 5. Study 6 is unique in that the MOEs are totally different and must be discussed separately.

CHAPTER 2

FIELD STUDY #1: SIGNING AND DELINEATION OF AN ARTERIAL CONCURRENT FLOW BUS LANE-- EAST COAST

Purpose

An evaluation of driver violation behavior within an urban arterial concurrent flow bus lane was undertaken to assess the effects of modifications to overhead signing information and the installation of a buffer zone delineator along the bus lane. It was reasoned that these new information displays would increase driver awareness of the existence of and rules of use governing the bus lane, which would in turn decrease the tendency to violate the lane.

Selection of signing treatments and buffer striping was based on previous laboratory testing (see Volume II, Chapter 6). It had been shown that certain sign designs convey the purpose and rules for use of the bus lane more clearly than others. Novel striping--combining prohibitive-permissive entry elements in its design--emphasized the lane had restricted status only part-time by signaling the driver to look for signing information. A heightened and continual awareness of the SUL facility would presumably result. However, a full assessment of the design effectiveness and impact of these new information displays would first require real-world application. The current study was undertaken for this purpose.

Experimental Design

Multiple Regression Data Analysis

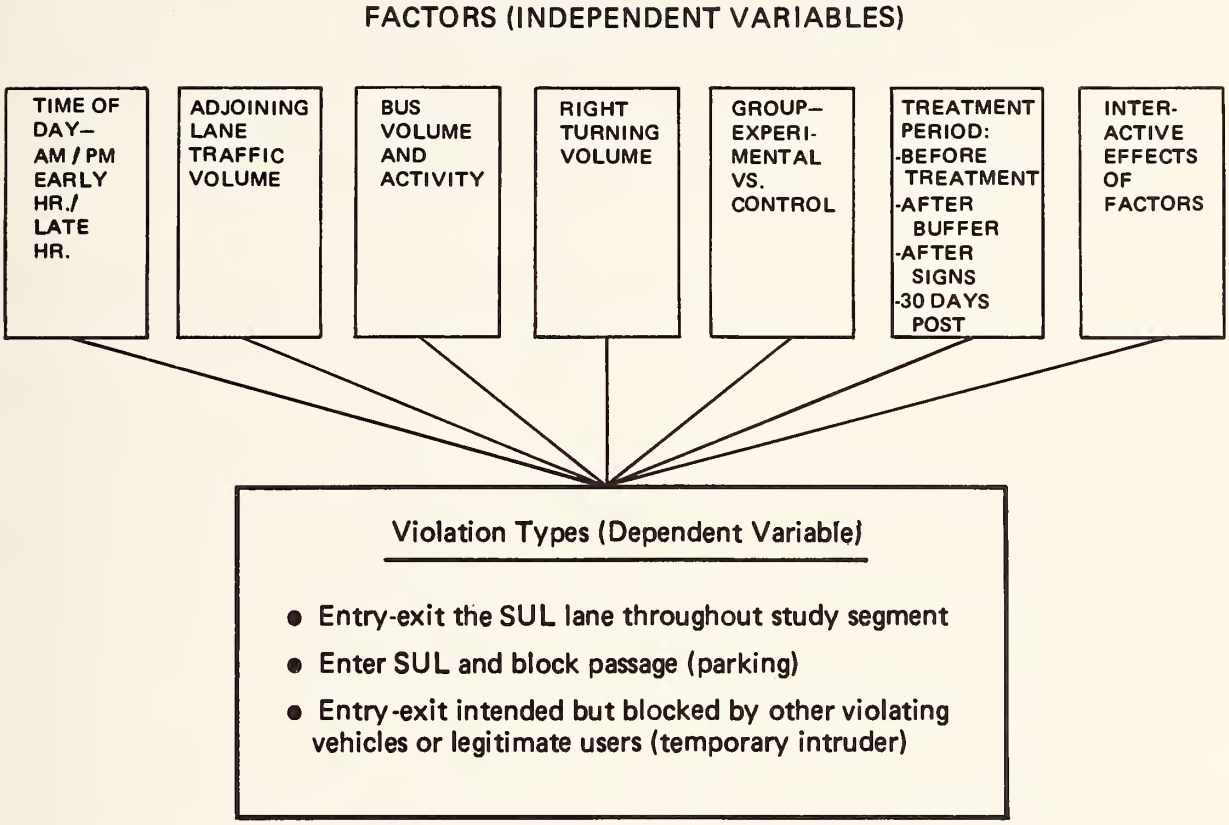
The study employed a multiple regression of factors which impacted upon driver violation behavior in the SUL driving

environment. Pilot observations of traffic operations within a given SUL segment revealed that a number of factors affected a driver's tendency to violate the SUL. In addition to the quality of signing and markings indicating both the existence of the lane and the rules for its use, these factors included such things as time of day, overall adjoining traffic volumes in the parallel general lanes, bus volumes and operating characteristics, and right turning vehicles in the SUL.

In order to account for the behavioral effects of the modified signs and new markings, as distinct from the effects of other operational factors, a technique was needed to isolate these effects without disturbing the real world traffic setting. The multiple regression paradigm offers a statistical technique for doing so. By monitoring overall traffic activity before and during the various modifications made to existing signs and markings, the effects of each factor on violation incidences can be predicted.

To employ the multiple regression technique, first a list of pertinent factors (independent variables) was generated. This was coupled with a coding scheme for violation behaviors (dependent variables) occurring in segments of the SUL. Table 4 presents these factors and violation codes as defined through pilot studies and pretesting. Application of the multiple regression model provides a breakdown of how much of the total population of violations is accounted for by each contributing factor. The effects of a particular treatment may thus be assessed simply by noting how much variability in violation behavior is accounted for with the successive addition of each factor. A linear equation emerges that can predict violations because each independent factor is weighted to measure its relative contribution to the solution. This is a statistical procedure based on the method of least squares.

Table 4. Factors Impinging Upon Violation Behavior in SUL


FACTORS (INDEPENDENT VARIABLES)
TIME OF DAY– AM / PM EARLY HR./ LATE HR.
ADJOINING LANE TRAFFIC VOLUME
BUS VOLUME AND ACTIVITY
RIGHT TURNING VOLUME
GROUP– EXPERI- MENTAL VS. CONTROL
TREATMENT PERIOD: -BEFORE TREATMENT -AFTER BUFFER -AFTER SIGNS -30 DAYS POST
INTER- ACTIVE EFFECTS OF FACTORS
Violation Types (Dependent Variable)
• Entry-exit the SUL lane throughout study segment
• Enter SUL and block passage (parking)
• Entry-exit intended but blocked by other violating vehicles or legitimate users (temporary intruder)

The difference between this technique for measuring group differences and the more traditional analysis of co-variance (ANCOVA) technique stems from different points of view about the overall population. In the linear regression, the hypothesis is that the coefficient weights on the contributing factors will be zero; in the ANCOVA, the hypothesis is that the means of all populations are the same. The rejection of the null hypothesis in the multiple regression still leaves a regression line indicating the effects of the various factors, which accounts for a large portion of total variance. In an ANCOVA paradigm, insignificant differences among sample means may or may not indicate the real effects of a specific treatment, since the effects of uncontrolled factors have been ignored or assumed to be constant. The multiple regression paradigm thus allows a more comprehensive assessment of operating factors in the traffic setting.

Data Collection Methods

Data collection of violation activity and operational characteristics occurred during four intervals:

- Before new signing or marking installations
- After Treatment 1: Buffer zone delineation
- After Treatment 2: Signing modifications implemented
- Post 30 days: 30 days after Treatment 2.

Five city-block segments were selected for data collection; with a four-block area designated as the experimental treatment area and a one-block segment upstream serving as a control site. Data collection intervals averaged 2 hours each day in the a.m. and p.m. peak periods (constrained by weather conditions). Each interval produced a set of counts and tabulations on all factors listed in Table 4. These sets became the basis for the multiple regression analysis.

Simultaneously, a second type of data was collected. Short on-site interviews were conducted with drivers along the SUL segment to assess their awareness ofthe restricted lane and its rules of use. The information gathered here was used to supplement and add insight to the violation behavior measures.

Site Description and Information Treatments

The SUL facility under study was located on State Street in downtown Rochester, New York. A section running from the Inner Loop to Lyell Avenue comprised the experimental treatment area. A control site section farther upstream from Lyell Avenue was located at Driving Park and Lake Avenues. At both of these sections, block areas for study were defined. Figure 2 shows a diagrammatic representation of both study sections, designating the block areas where data were taken. (Note that outbound State Street changes to Lake Avenue past Lyell Avenue).

The State Street experimental area is a two-way, downtown-type facility, and the SUL operates in both a.m. and p.m. peaks. The roof of the nine-story Kodak Executive Headquarters Building, in the midst of the site, served as the vantage point from which data were recorded. The control area outbound from the downtown area consisted of one block for a.m. peak data and one block for p.m. peak data, and served as a kind of matched section for the experimental area. This control area was monitored to note any seasonal variations in overall traffic patterns throughout the experimental treatment period.

Based on driver information requirements analysis and laboratory study (see Volume II) related to concurrent-flow priority lanes, modifications in overhead signing and installation of a buffer zone delineation were implemented. Signing

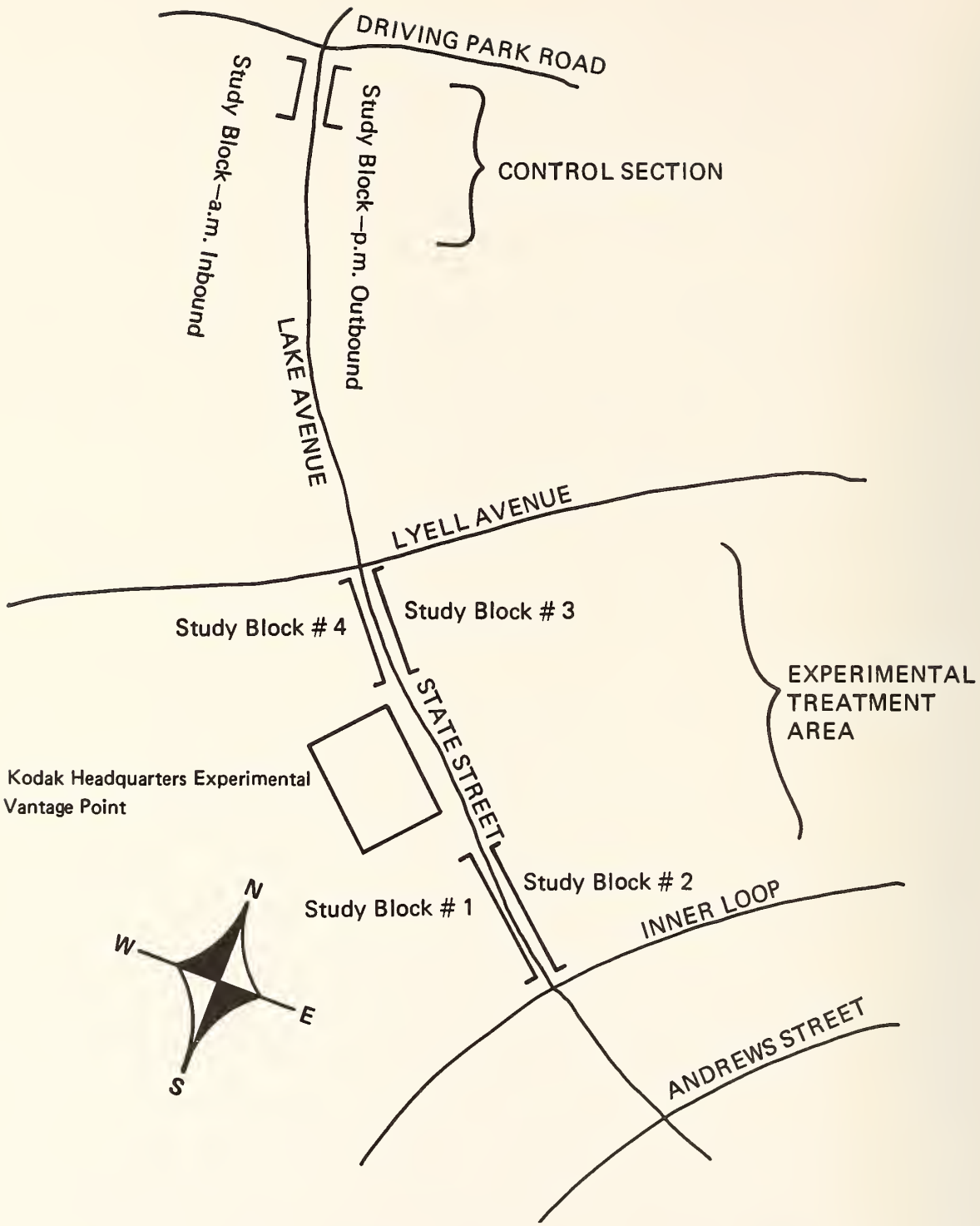


Figure 2. Experimental and control study block areas along State Street concurrent flow bus lane facility —Rochester (not to scale).

was modified to provide a thorough system of information to the driver as he approached, entered the SUL facility, passed through, and exited. Larger, bolder print on all overhead system signs, along with the incorporation of the diamond symbol, were implemented.

The delineation scheme employed was a new concept, a striping to separate the SUL from the adjoining traffic lane. This design consisted of two solid white lines with small diamonds embedded between the lines at 40-foot intervals. The solid line serves as a prohibitive agent, while the spaced diamonds are somewhat permissive, signaling the driver to seek signing information to explain this symbology. Figure 3 presents the basic design and dimensions of the diamond buffer zone. Figure 4 is a series of photographs along State Street in the experimental treatment area. These present views of the new signs, buffer zones, and combinations of both from various perspectives.

Methods and Measures

Counts and tabulations of traffic and violation activities during data collection intervals were procured via time-lapse photography and real-time manual coding. For a given day, a trained experimenter positioned two super-8 movie cameras (Minolta XL-400) atop opposite corners of the Kodak building overlooking the four-block experimental treatment area of State Street (see Figure 2). A ground-level observer simultaneously monitored the one-block control section farther upstream. Filming was set at one frame per second for 2 hours in the morning rush and 2 hours in the evening. After development, the super-8 movies were scored by trained coders who recorded violation behaviors, bus counts per hour, adjoining traffic volumes, right turning

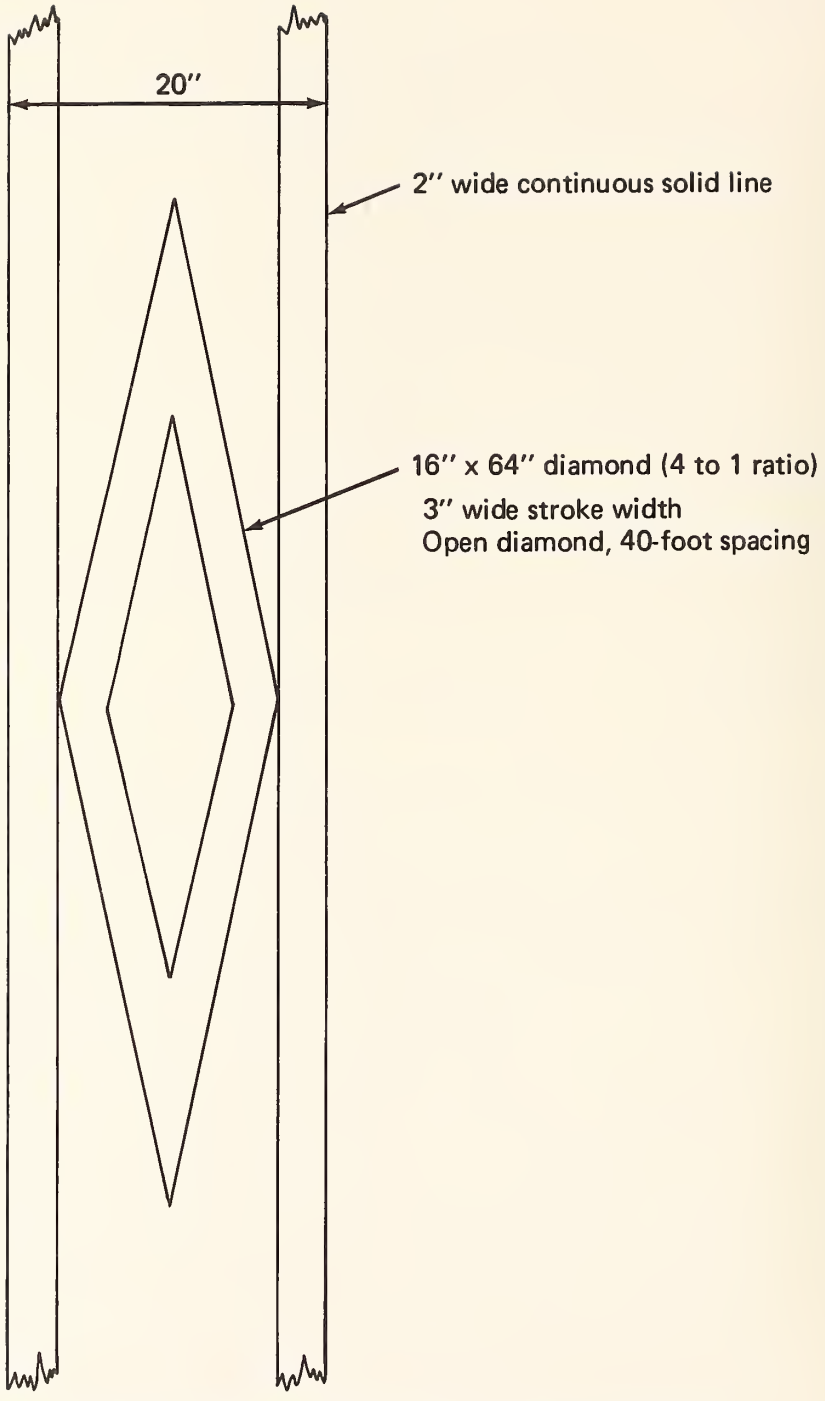


Figure 3. Design of diamond buffer zone pavement marking.

A. Approach signing in advance of the loop.

B. Modified SUL sign based on MUTCD standard.

Figure 4. State Street concurrent flow bus lane – experimental treatment area showing modified signs and new striping design –Rochester.

C. Close-up view of new striping design.

D. Street level view of SUL showing sign and markings.

Figure 4. (Continued)

E. View from atop Kodak building along State Street SUL showing effects of new striping along curb bus lanes.

Figure 4. (Continued)

movements, etc. (see factors listed in Table 4). These codes and tabulations were keypunched and processed through the multiple regression program.

Short on-site interviews were conducted during the "before data collection" interval, and "post 30" (30 days after sign installations). As drivers traversed the SUL facility in the experimental treatment area, some were briefly detained by the red cycle of the traffic signal at various intersections. These vehicles were approached by interviewers carrying an 8½" x 11" clipboard with the large, bold message "Traffic Study" printed on the back panel. This device minimized the explanation required, and interviews could proceed quickly. Cars sampled began with the first car stopped at each red cycle, and continued back in line as time permitted.

Figure 5 presents a copy of the interviewers' guide to questions asked. In most cases, only the first two questions could be covered before the green light terminated the interview. The sampling was thus intended to reveal drivers' basic awareness of the SUL, rules, purposes, and, if possible, reactions to its operation. The critical issue was awareness and acknowledgment of the signing and marking information. Secondarily, ideas, complaints, and other reactions to the facility were assessed when possible to supplement the awareness question.

Results and Discussion

Four multiple regression runs were processed to derive an equation predicting violation behavior in the Rochester SUL. Run number one entered 39 variables in three steps. The first step considered the effects of control operational variables as listed below:

BEFORE DATA

1. Are you aware of a special use for any lane on this street during rush hour?

☐ YES

2. Which lane is it and who can use it?

_____

_____

3. Do you think the special bus lane is a good idea?

_____

_____

☐ NO

2. About how often do you drive by here?

_____

_____

3. The right lane is for buses and right turns only. Do you think this is a good idea?

_____

_____

AFTER TRT 2

1. Did you see any information about the use of the right lane on this street?

☐ YES

2. What did you see?

_____

_____

3. What did they (signs, etc.) tell you?

_____

_____

☐ NO

2. Did you see these signs and markings? (show photo)

☐ YES ☐ NO

3. What do they (signs,etc.) tell you?

_____

_____

Figure 5. Red-light interview forms.

Multiple Regression

Dependent Variable: Violation, Number of Violations

Variable(s) entered on Step Number 1:	Time	a.m. or p.m.
	Hour	
	Buses	Number of buses

Step 2 considered the experimental treatment variables and their interactions:

Multiple Regression

Dependent Variable: Violation, Number of Violations

Variable(s) entered on Step Number 2:	Group	After buffer
	Trt 1	After buffer
	Trt 2	After buffer and signs
	Post 30	30-day acclimation
	GrpTrt 1	Interaction group x Trt 1
	GrpTrt 2	Interaction group x Trt 2
	GrPost 30	Interaction group x Post 30

Finally, Step 3 introduced all of the interactive effects of the above listed variables:

Multiple Regression

Dependent Variable: Violation Number of Violations

Variable(s) entered on Step Number 1:

VolGrPo	Interaction Volume x GrPost 30
TimeTrt 1	Interaction Time x Trt 1
TimeTrt 2	Interaction Time x Trt 2
TimePost	Interaction Time x Post 30
TimeGrp	Interaction Time x Group
TimeGrT 1	Interaction Time x GrpTrt 1
TimeGrT 2	Interaction Time x GrpTrt 2
TimeGrPo	Interaction Time x GrPost 30
HourTrt 1	Interaction Hour x Trt 1
HourTrt 2	Interaction Hour x Trt 2
HourPost	Interaction Hour x Post 30
HourGrp	Interaction Hour x Group
HourGrT 1	Interaction Hour x GrpTrt 1
HourGrT 2	Interaction Hour x GrpTrt 2
HourGrPo	Interaction Hour x GrPost 30
BusTrt 1	Interaction Buses x Trt 1
BusTrt 2	Interaction Buses x Trt 2
BusPost	Interaction Buses x Post 30
BusGrp	Interaction Buses x Group
BusGrT 1	Interaction Buses x GrpTrt 1
BusGrT 2	Interaction Buses x GrpTrt 2
BusGrPo	Interaction Buses x GrPost 30
VolTrt 1	Interaction Volume x Trt 1
VolTrt 2	Interaction Volume x Trt 2
VolPost	Interaction Volume x Post 30
VolGrp	Interaction Volume x Group
VolGrT 1	Interaction Volume x GrpTrt 1
VolGrT 2	Interaction Volume x GrpTrt 2

With the addition of each variable list, prediction of violations was significantly achieved (.01); this violates the assumption for homogeneity of regression. Also, the interpretation of these 39 variables was felt to be unmanageable. Thus the second regression run sought to reduce this large number by eliminating some factor within these variables that was not contributing significantly to the overall prediction. The hour factor (early hour/late hour) met this criterion in all steps; that is, its impact alone or interactively with other factors did not produce a significant F score at any point in the run.

Run number two then consisted of a reduced number of factors, down now to 31. These were entered in five steps as shown below. Note that group was entered separately, then group treatment interactions entered separately (Steps 3 and 4) in an attempt to tease out the effects of these control vs. experimental group factors.

```
Concurrent Flow Bus Lanes
File      NROCH3      (Creation Date = 13-Jun-80)

Dependent Variable:          Violation       Number of Violations

Variable(s) entered on Step Number 1:  Time        a.m. or p.m.
                                       Buses       Number of Buses

Dependent Variable:          Violation       Number of Violations

Variable(s) entered on Step Number 2:  Trt 1       After Buffer
                                       Trt 2       After Buffer and Signs
                                       Post 30     30 Day Acclimation

Dependent Variable:          Violation       Number of Violations

Variable(s) entered on Step Number 3:  Group

Dependent Variable:          Violation       Number of Violations

Variable(s) entered on Step Number 4:  GrpTrt 1    Interaction Group x Trt 1
                                       GrpTrt 2    Interaction Group x Trt 2
                                       GrPost 30   Interaction Group x Post 30

Dependent Variable:          Violation       Number of Violations

Variable(s) entered on Step Number 5:  VolGrPo     Interaction Volume x GrPost 30
                                       TimeTrt 1   Interaction Time x Trt 1
                                       TimeTrt 2   Interaction Time x Trt 2
                                       TimePost    Interaction Time x Post 30
                                       TimeGrp     Interaction Time x Group
                                       TimeGrT 1   Interaction Time x GrpTrt 1
                                       TimeGrT 2   Interaction Time x GrpTrt 2
                                       TimeGrPo    Interaction Time x GrPost 30
                                       BusTrt 1    Interaction Buses x Trt 1
                                       BusTrt 2    Interaction Buses x Trt 2
                                       BusPost     Interaction Buses x Post 30
                                       BusGrp      Interaction Buses x Group
                                       BusGrT 1    Interaction Buses x GrpTrt 1
                                       BusGrT 2    Interaction Buses x GrpTrt 2
                                       BusGrPo     Interaction Buses x GrPost 30
                                       VolTrt 1    Interaction Volume x Trt 1
                                       VolTrt 2    Interaction Volume x Trt 2
                                       VolPost     Interaction Volume x Post 30
                                       VolGrp      Interaction Volume x Group
                                       VolGrT 1    Interaction Volume x GrpTrt 1
                                       VolGrT 2    Interaction Volume x GrpTrt 2
```

Even though some differences in prediction occurred, homogeneity of regression was not achieved after input of all variables. Close examination of the data revealed that violation trends as affected by the new signs and markings would always be subject to the surrounding volume and level of bus activity. In all steps, these two factors contributed significantly to the variance accounted for by the multiple R.

Since the effects of bus activity and volume could not be reduced to a single factor loading each, it was felt that the best way to assess the effects of the experimental treatment

variables (signs, markings, group, etc.) was to look at violation behavior at different levels of bus and volume activity. A series of graphs were prepared to illustrate the regression equations derived under various levels of bus activity and volumes of traffic. In all, six graphs were plotted as follows:

#1 Low Bus Level of Activity, a.m. data period

#2 Low Bus Level of Activity, p.m. data period

#3 Medium Bus Level of Activity, a.m. data period

#4 Medium Bus Level of Activity, p.m. data period

#5 High Bus Level of Activity, a.m. data period

#6 High Bus Level of Activity, p.m. data period

Each graph presented violations for each bus level in the a.m. or p.m. period with points at three levels of volume, high, medium, and low. Figures 6 through 11 present these data. In defining bus and volume levels as high, medium, and low, the mean from the raw data was used as medium, with +1 standard deviation as high and -1 standard deviation as a low level. These three points then revealed the regression lines for each plot.

Interpretation of the regression lines reveals several trends indicative of the effects of the group factors (experimental vs. control) and the treatment factors (markings (Trt 1), signs (Trt 2)). Graphs were divided into the a.m. and p.m. periods simply to ease interpretation and decrease number of regression lines on any one plot.

The first trend permeating all graphs is as overall bus level and volume level increase, violation activity increases significantly in the control block area, regardless of a.m. or p.m. period. In the experimental treatment area, violations

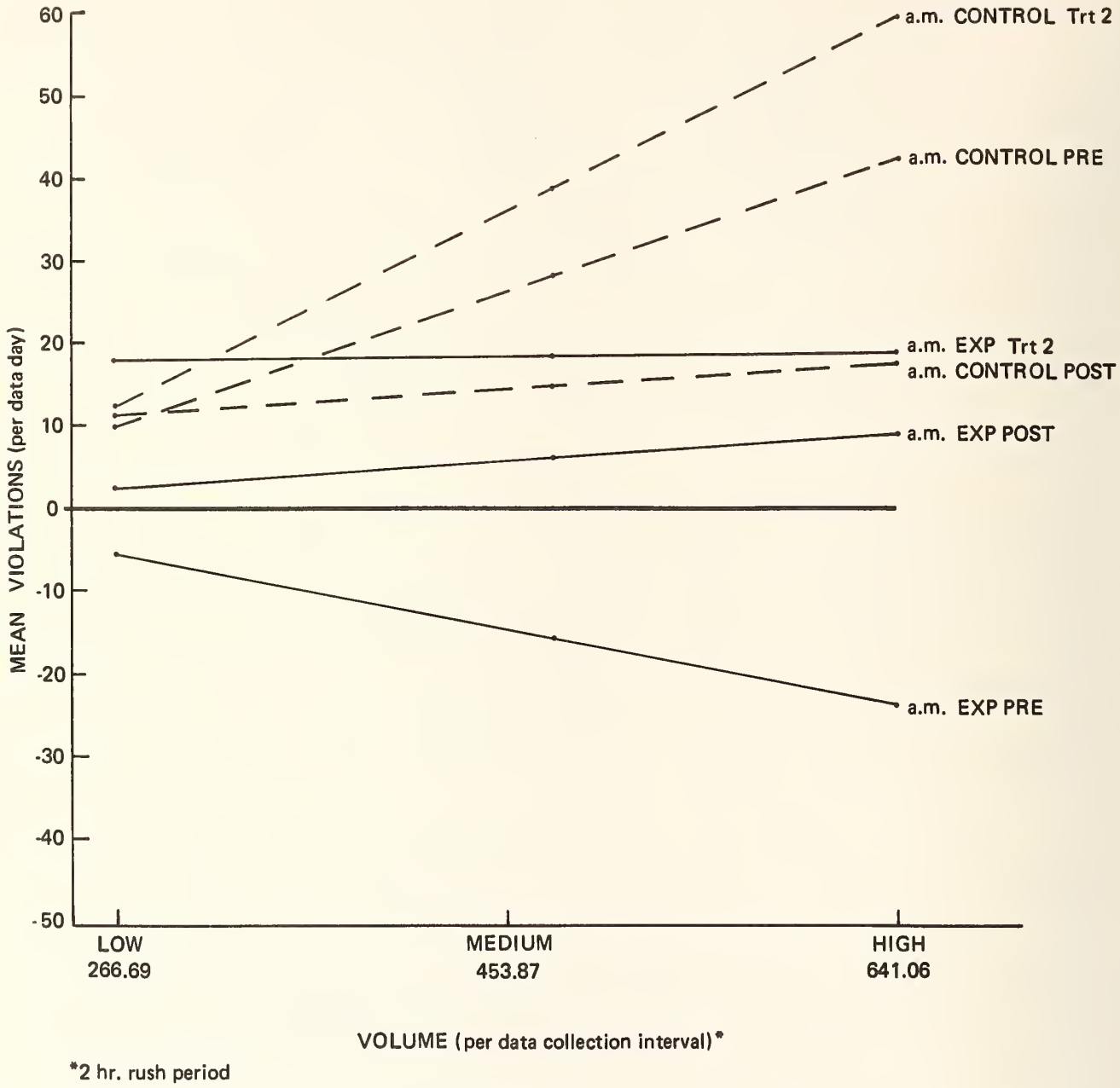


Figure 6. Regression lines, low bus activity level, a.m. data period—Rochester.

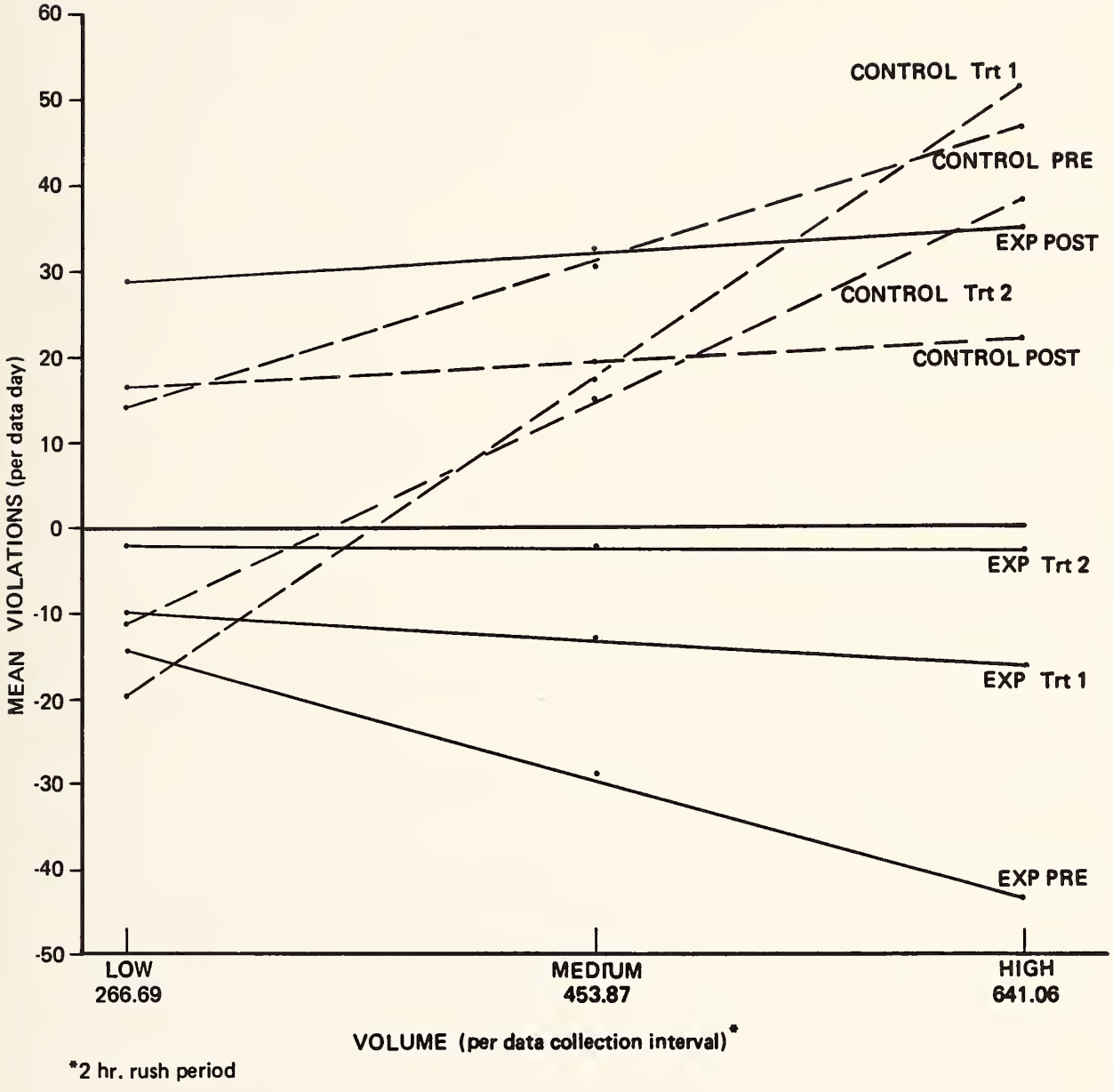


Figure 7. Regression lines, low bus activity level, p.m. data period—Rochester.

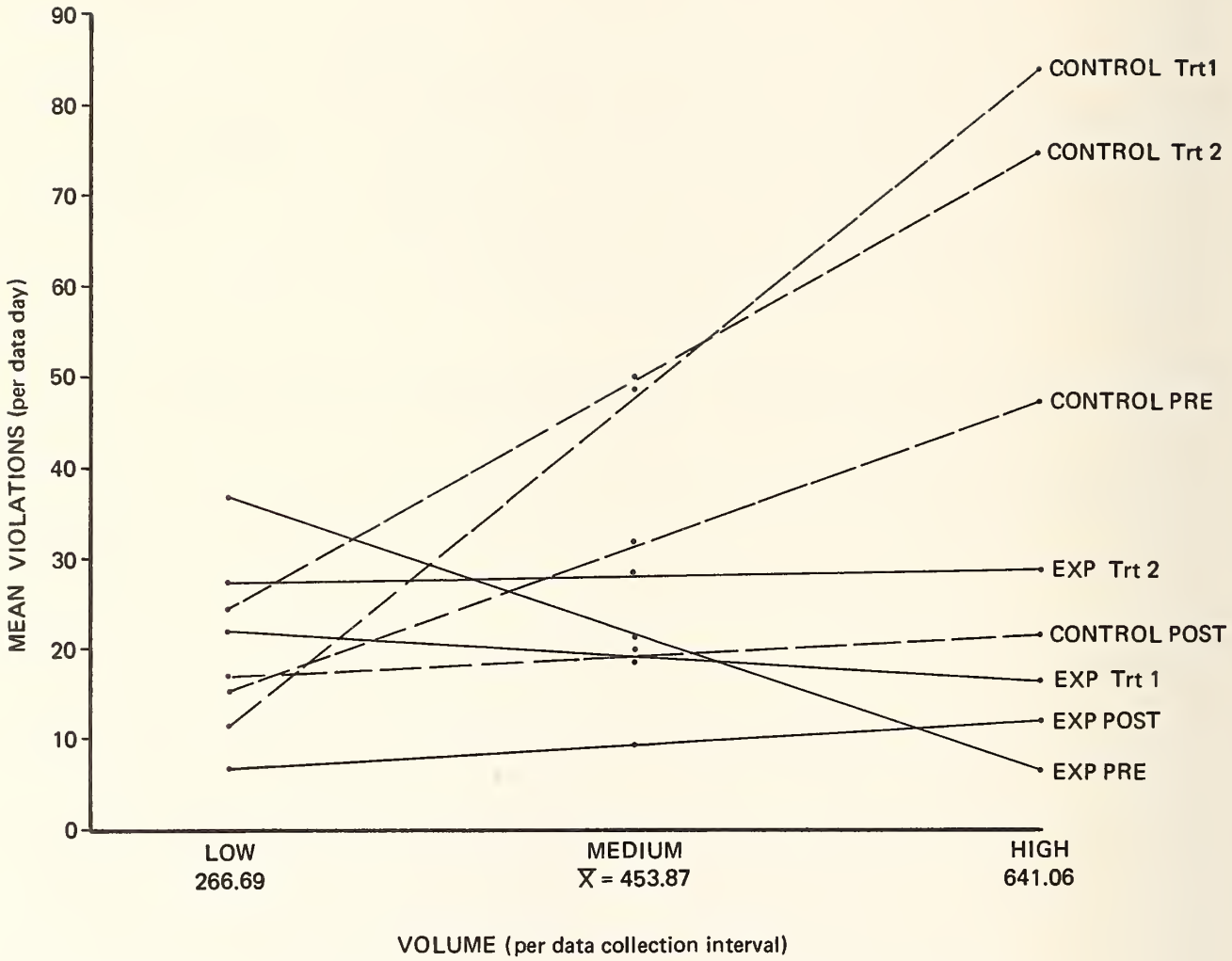


Figure 8. Regression lines, medium bus activity level, a.m. data period—Rochester.

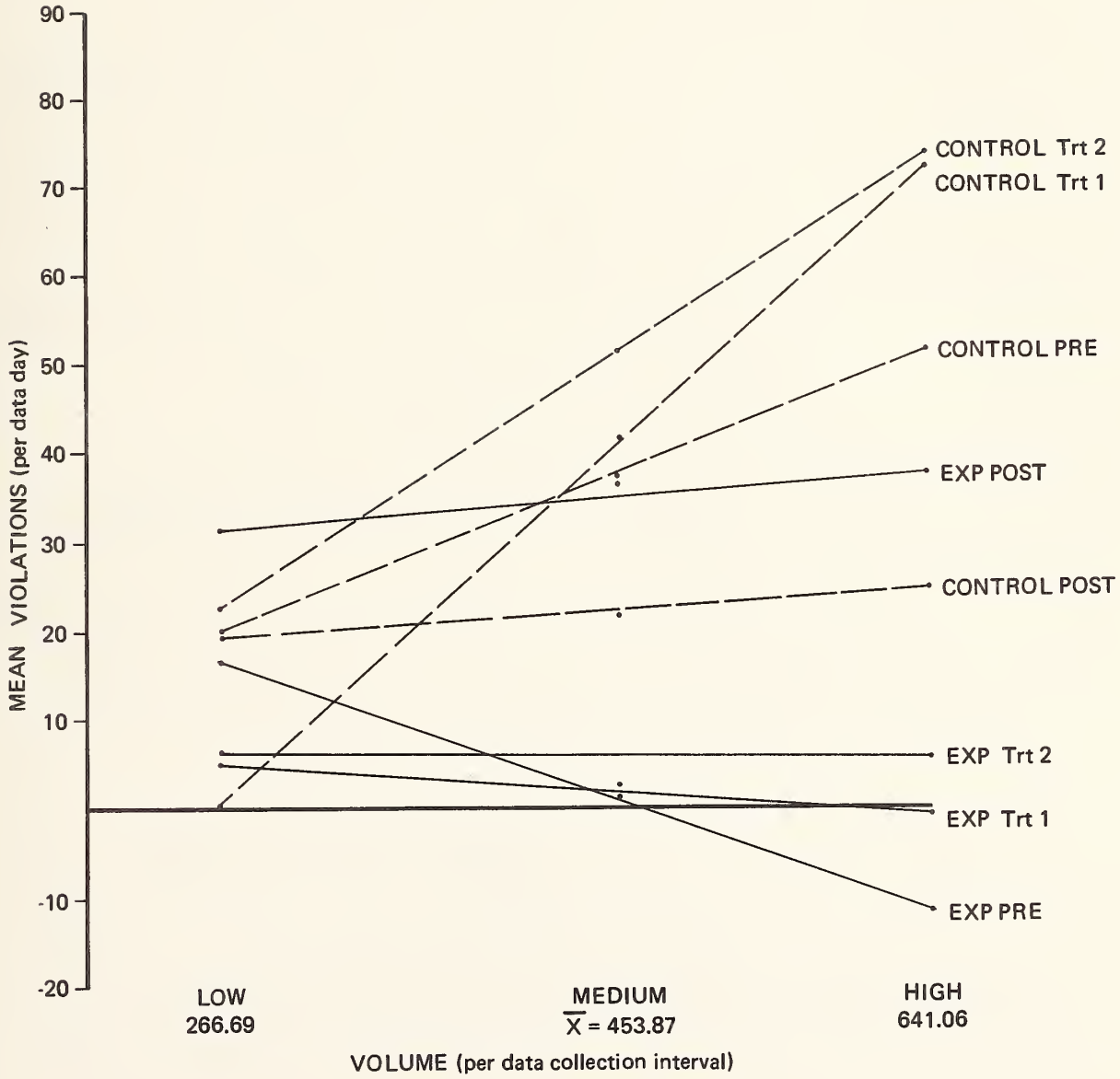


Figure 9. Regression lines, medium bus activity level, p.m. data period— Rochester.

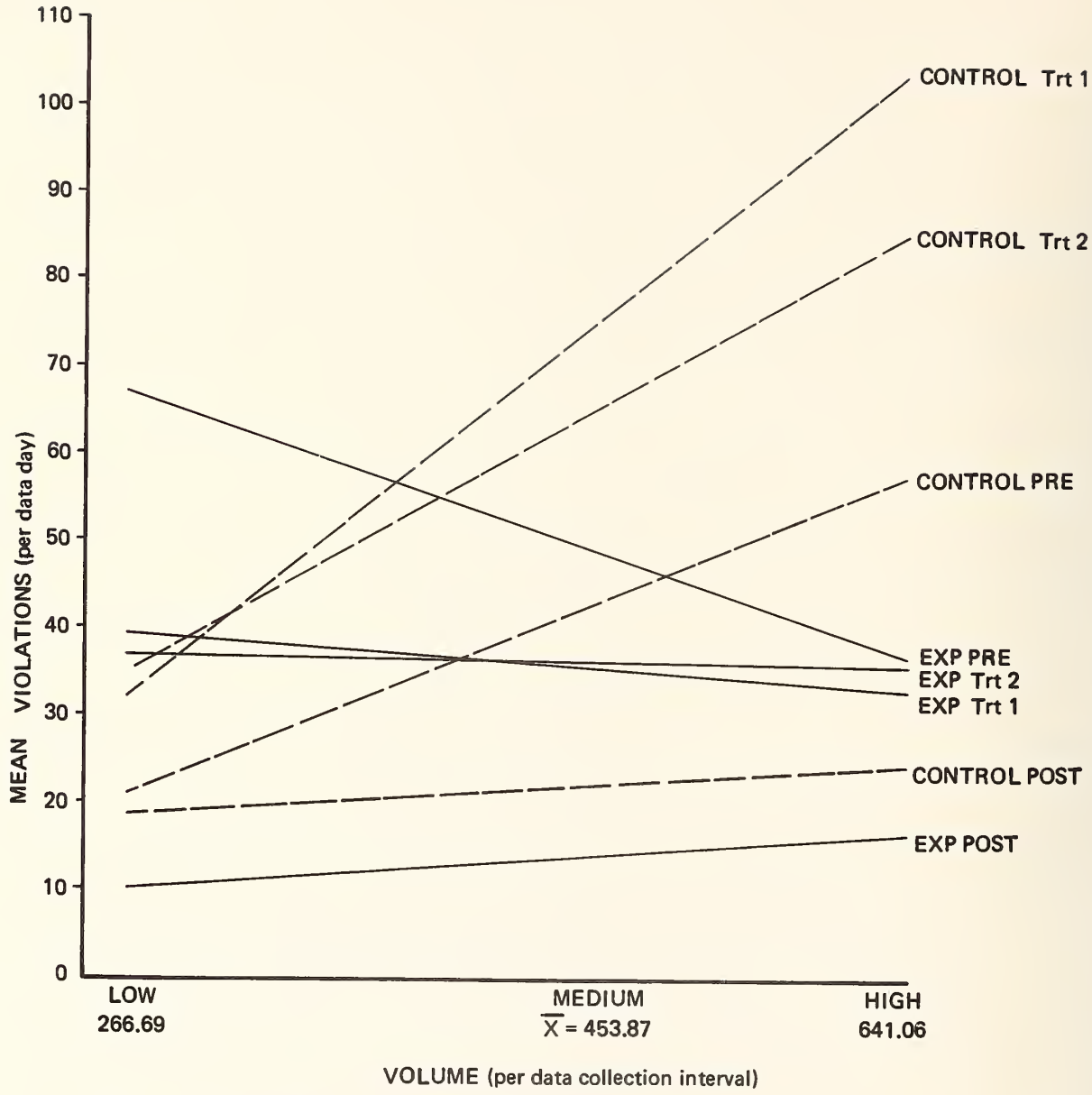


Figure 10. Regression lines, high bus activity level, a.m. data period—Rochester.

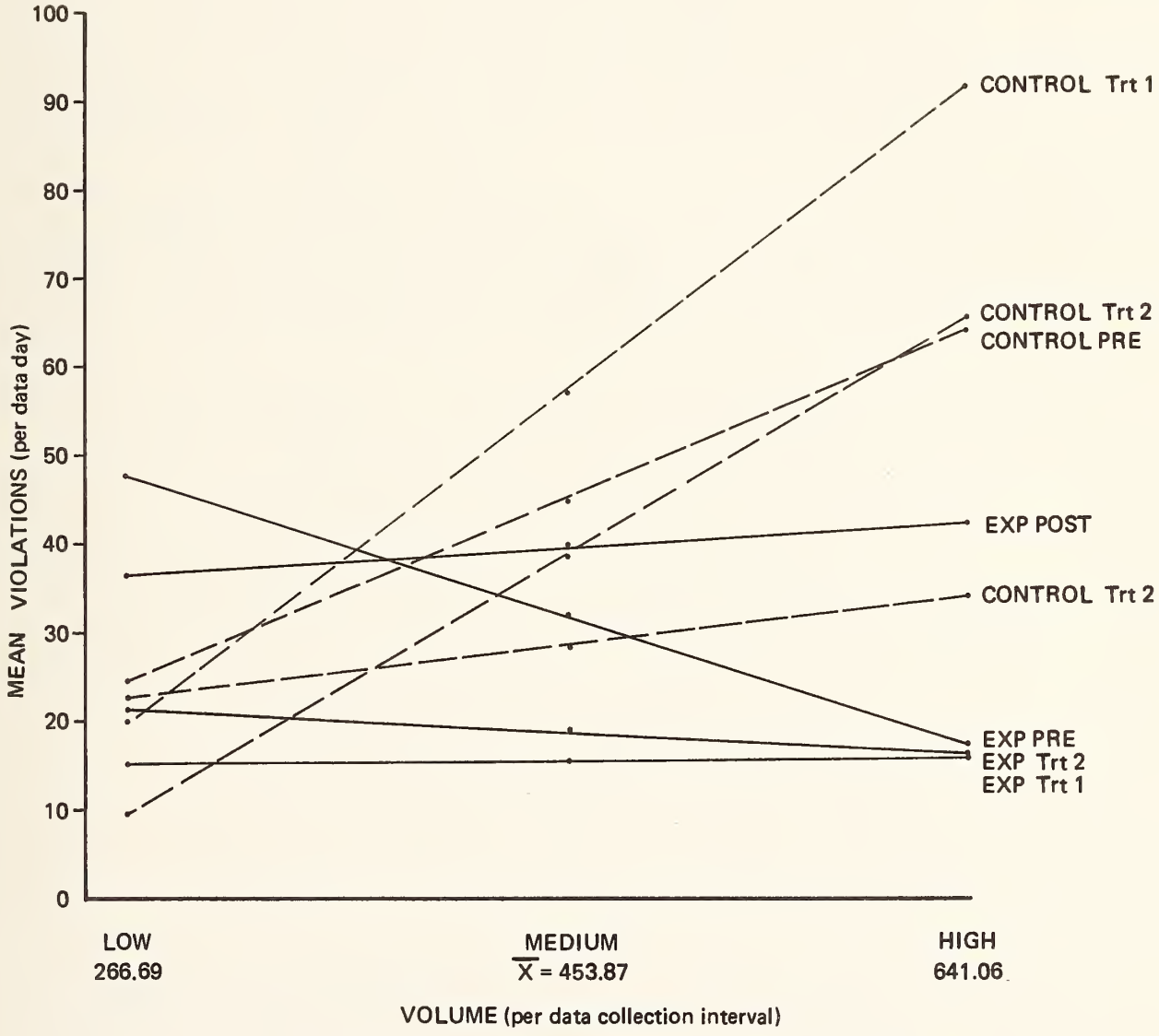


Figure 11. Regression lines, high bus activity level, p.m. data period–Rochester.

either decrease or remain the same with increasing volume, and increase only slightly in overall occurrence with increased bus activity.

These overall increases for the control area say that with increased volume of traffic on the facility, more violations will also occur. Further examination of the control group lines also shows that overall trends in traffic behavior did not change during the pretest and Treatment 1 and 2 periods, but the Post 30 period had some slightly different characteristics. This may be attributed to seasonal variations, possibly since these data were collected close to a holiday. In general, the control patterns consistently show violation increases with increased volume, and the overall violation level increases with more bus activity.

The effects of the marking and signing treatments within the experimental four-block area are more difficult to assess; however, there does seem to be an initial impact of the buffer strip (Treatment 1) upon violation rate. During the pre-treatment condition, violations were fairly high during low volume conditions, and then declined as volume increased. After the buffer application, violations were at a constant low level throughout increasing volume and bus levels. The same trend is evident in the Treatment 2 (sign application) condition although it is not as pronounced. The Post 30 condition exhibits a return to high level violations following the pattern noted in the control block area.

How is the leveling of violations explained in the experimental area as a result of the buffer strip and signs? In the pre-condition, violations were high in a low volume setting because cars used the SUL as an open lane, traveling oblivious to the old signing. With increasing traffic volume, these same

travelers were not free to choose the SUL as an open path since it was often blocked by parking violations, e.g., more traffic in the area during the peak hours meant more double parking in the lane, thus preventing sail-thru violations. Installation of the new markings and signs impacted sail-thru violators in the low volume condition to decrease their numbers by making them aware of the existence of the SUL. After acclimation, however, the overall effects of the treatment began to wash out. This is borne out in the red-light interview data taken before and after the treatment installations (to be presented later).

Given the interest in the experimental treatment area alone, and also the parking violation behavior therein, two final multiple regression equations were run. The first of these considered the violation variable without inclusion of the control group data. Fifteen variables were entered in three steps as shown below:

Dependent Variable:	Violation	Number of Violations
Variable(s) entered on Step Number 1:	Time	a.m. or p.m.
	Buses	Number of Buses
	Volume	
Dependent Variable:	Violation	Number of Violations
Variable(s) entered on Step Number 2:	Trt 1	After Buffer
	Trt 2	After Buffer and signs
	Post 30	30 Day Acclimation
Dependent Variable:	Violation	Number of Violations
Variable(s) entered on Step Number 3:	VolPost	Interaction Volume x Post 30
	TimeTrt 1	Interaction Time x Trt 1
	TimeTrt 2	Interaction Time x Trt 2
	TimePost	Interaction Time x Post 30
	BusTrt 1	Interaction Buses x Trt 1
	BusTrt 2	Interaction Buses x Trt 2
	BusPost	Interaction Buses x Post 30
	VolTrt 1	Interaction Volume x Trt 1
	VolTrt 2	Interaction Volume x Trt 2

Note that these are entered in the same order as the previous regression, starting with control factors, then experimental factors, followed by interaction among these. With each step, prediction capability was increased, and multiple R increased significantly. Thus, only a complex accounting of these factors

and their interactions would explain violations, as in run number two. Nothing was gained in explanatory value by dropping the contribution of the control block area.

The final regression run was an attempt to zero in on the parking obstruction type of violation (item two in Table 1 for dependent variable violation types). These data were coded and tabulated from the time-lapse films and keypunched as before. In three steps, fifteen variables were entered, the same as in regression run number three above. The addition of the step interaction factor only accounts for about 31.2% of the variance. This parking measure is subject to the same contingencies of bus activity and volume variabilities as the violation counts. The significant F recorded at the end of the regression indicates that unrecorded factors have not been figured into the equation. It is suggested that further definition of this measure be attempted in future study, perhaps by recording length of parking stay in the SUL, number of parked vehicles in the SUL at any one interval, etc. The best predictive regression lines have emerged from run number two, discussed at length above.

In support of the regression data presented above, red-light interviews of drivers along the SUL were conducted. The method and format of the interviews were described in the previous section. Over 150 drivers were interviewed before new signing and buffer strip installations, and approximately 100 were interviewed after the installations. Drivers were not separated by violator/non-violator since all of the drivers caught in the SUL by a red light interviewer turned right, a legal maneuver, and the few sail-thru violators could not be trapped by the red signal. In fact, many parking violators impeded possible sail-thru violators, and so were actually caught in the general lanes. Table 5 presents the interview data as recorded during both before and after treatment installations.

Table 5

Red-Light Driver Interviews--
Rochester SUL

Before Signs & Markings

Sample Size = 160

Q1. Are you aware of a special use for any lane on this street during rush hour?

Yes 37% — No 63%

Q2. Which lane is it?

Right (SUL)	91%
Other	9%

How often do you drive by here?

Everyday	64%
Somewhat less	14%
Infrequently	22%

Q3. Do you think the/a special bus lane is a good idea?

Yes 50% — No 50% — I don't know 3%

After Signs & Markings

Sample Size = 150

Q1. Did you see any information about the use of the right lane on this street?

Yes 50% — No 50%

Q2. What did you see?

Signs	51%
Markings	8%
Both	41%

Did you see these signs and markings (photo shown)?

Yes	53%
No	47%

Q3. What do/did they (signs & markings) tell you?

Bus lane 84% — Other/I don't know 16%

In direct support of the regression data (run number 2), before the sign and buffer strip installations, the majority of drivers (63%) did not know of the existence of the SUL, even though 64% of these drove the facility every day. It may be concluded here that drivers regarded the SUL as a free travel or double-parking lane for their use. Only 37% of interviewees allowed knowledge of the SUL and its purpose. When questioned about whether the idea of an SUL for buses was a good idea or concept, drivers overwhelmingly indicated that it was. Obviously what is good in theory and what impacts on actual behavior are two diverse entities.

With the installation of the buffer strip and overhead signing modifications, a change in driver awareness of the SUL was recorded. At least half of the interviewees reported they knew of the bus lane, and had noticed the signs and markings. More attention focused on the signs or the signs and markings together rather than first on the markings. With some prodding via a small hand-held photo of the SUL, another 25% of drivers acknowledged that they had seen the new installations and could correctly recite their intended SUL meaning. Apparently this increased awareness did impact potential violators, at least in the low volume traffic condition, for a period just following the new installations.

Conclusions

- The buffer zone and signing treatment serve to lower violations under conditions of low traffic volume.
- Effects of buffer zone and signing are washed out during high volume conditions since drivers tend to use the lane for double parking and passenger pick-up.

- Overhead signing and buffer zone markings are more noticeable as a single system rather than as separate entities.
- In existing SUL operations, many drivers become oblivious of SUL existence after acclimation.
- Some effects of new signs and markings diminish after the 30-day acclimation period.
- Drivers support SULs in theory, but are not responsive to the constraints of an SUL when they are driving.

CHAPTER 3

FIELD STUDY #2: SIGNING AND DELINEATION OF AN ARTERIAL CONCURRENT FLOW BUS LANE-- WEST COAST

Purpose

The buffer zone delineation concept was a novel one, and a second field test in a different part of the country was considered necessary to determine if any impact was city specific, or was more generalizable. A slightly different comparison could also be made for signing. In Rochester, the design and format of the overhead signs were changed, but in San Francisco, shoulder versus overhead mounted signs could be tested. San Francisco had a signing and marking system that essentially conformed to MUTCD standards, so here was a test of the experimental system versus the current standard. Also, San Francisco served as a more complete system test in that the entire SUL was re-signed and the buffer zone added.

Since shoulder mounted signs, solid white line delineation, and mid-lane diamonds constituted the original system, and because the violation rate was considered high by city authorities, the null hypotheses tested in this study were:

1. There will be no difference between the experimental signing and delineation system and the existing system.
2. The buffer zone will not change violation rates compared to the solid white line.
3. Overhead signing will have no effect on violation rates compared to shoulder mounted signs.

This study was unique in that the entire SUL was re-signed and marked. Such a change was possible only through the graciousness and timely cooperation of the Office of Service and Demonstration Programs, Urban Mass Transit Administration. Mr. Marvin Futrell and Mr. Joseph Goodman of UMTA became aware of this project, talked to FHWA and BioTechnology, and suggested the possibility of a cooperative effort. UMTA funded a project in San Francisco which, in part, included the re-signing and striping of Post and Sutter Streets; Geary and O'Farrell would not be changed. With the assent and cooperation of the City of San Francisco, BioTechnology recommended the sign and delineation designs. These were modeled by the city for their project, and both an UMTA contractor (Systan Corporation) and BioTechnology performed evaluations, but on different parts of the SUL. The magnitude of the re-signing and striping thereby available for study far exceeded project resources.

Experimental Design

Two parallel one-way couplets or pairs, each with similar SUL lanes, served as control and experimental streets.

- Post Street: inbound, experimental
- Sutter Street: outbound, experimental
- O'Farrell Street: inbound, control
- Geary Street: outbound, control.

The experimental sequence was identical to that used in Rochester (Study #1). In other words, as far as possible, Study #2 was a west coast replica of Study #1. Briefly, "before" data were collected on both control and experimental streets in July/August, and the buffer zone was installed on the experimental streets and data collected in early December. Overhead signing

was installed early in February and data were collected, and 30 days later the "after acclimation," or "Post 30," data were collected.

Site Description and Information Treatments

The SUL lanes on the four San Francisco streets were reserved for buses and right turning vehicles, and operated 24 hours a day, 7 days a week. Each SUL ran from Union Square, eight blocks to Van Ness Street, and various distances (2-6 blocks) past Van Ness. Due to the hills of San Francisco, one data collection vantage point allowed collection of data along the four blocks from Van Ness to Hyde Street (see Figure 12A). Each street consisted of two through lanes, an SUL lane, and parking lanes on both sides of the street. Figure 12B shows one street with the "before" striping and marking. The white lines were 8-inch thermoplastic, but the diamonds and lettering were badly worn or illegible in most places. This figure shows the arrangement of parking within the SUL. Double parking is allowed in San Francisco for delivery vehicles.

Figure 13A shows the "before" shoulder mounted signs posted along all the SULs. Figure 13B depicts the buffer zone installed on the experimental streets. The only difference between this and the buffer zone in Rochester was the one 8-inch (rather than 2-inch) stripe. Since the stripe was thermoplastic, removal was not an option and it had to be incorporated into the buffer zone design.

The signs finally used were a compromise because they were hung from trolley electric line support cables. Due to weight and wind loading constraints, the signs were relatively small and mounted rather high. To obtain adequate legend legibility, the

A. Four block view from data collection vantage point.

B. "Before" delineation.

Figure 12. Site and before treatment photos—San Francisco.

A. "Before" shoulder mounted signs.

B. Buffer zone delineation.

Figure 13. Site photos–San Francisco.

right turn legend had to be smaller and shorter. At cross streets where there was no right turn, the legend was as shown in Figure 14A, but where right turns were allowed, the words RIGHT TURN OK were added along the bottom (see Figure 14B).

Methods and Measures

The data collection techniques and measures of effectiveness were the same as those used in Rochester. Time-lapse films were made of vehicle movement along a four-block section of each experimental (E) and control (C) street. Although each SUL operated full time, there was sufficient traffic (car, bus, and violator) volume to warrant data collection only during peak hours. Therefore, data collection took place on Post (E) and O'Farrell (C) Streets for 2 hours in the morning (inbound) rush hours (7-9 a.m.), and on Sutter (E) and Geary (C) Streets during the evening (outbound) rush hours (4-6 p.m.).

From the time-lapse film, control measures for bus volume, vehicle volume in the lane adjoining the SUL lane, number of right turns from the SUL, and time of day and hour were gathered.

Measures of effectiveness* were also scored from the film. These included:

- SUL violation--enter the SUL at the beginning of a block and continue on to the next block.
- SUL violation--enter the SUL midblock and continue on to the next block.
- SUL weaving violations--enter and exit the SUL in the same block.

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*Another MOE, bus time and delay, which was being collected by the city was not available at this writing.

Overhead signing.

Overhead signing–before a street where right turns were allowed.

Figure 14. Signing and delineation treatments applied to the experimental SULs –San Francisco.

- Number of vehicles intruding on SUL to get to parking, alleys, garages, etc.
- Weaving out--enter the block on an SUL and weave out midblock.
- Parked car/weave--enter the block on an SUL and weave around a double-parked vehicle.

To gain insight into driver awareness of the SUL and to aid interpretation of vehicle movement data, short red-light interviews (described in Study #1, Chapter 2) were conducted during the "before" and again during the "30-day after" data collection periods. Interviews were conducted on the E and C streets concurrent with time-lapse filming.

Results and Discussion

Time-lapse film scoring was accomplished in the manner described for Study #1 (Rochester). The various types of violations were grouped into three categories:

- Number of violations--car does not leave SUL by the end of the block.
- Temporary intrusions--cars weave in and/or out of SUL within a block.
- Parking vehicle legally double-parked but blocking the SUL.*

After editing and keypunching, a step-wise regression analysis was performed.

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*Note that this is a different definition than in Rochester, where parking in the SUL was illegal.

As in Study #1, the control variables (number of right turns, number of buses, adjoining lane volume, a.m. and p.m.) were entered into the equation first. Number of violations was used as the dependent variable. Then the four treatment periods ("before," Treatment 1--buffer zone, Treatment 2--overhead signing, and 30-day "after") and groups E and C were added, followed by the interactions of the control variables with the experimental variables. Using the two-, three-, and four-way intersections of the control and experimental variables, a total of 61 variables were in the equation. Each step resulted in a significant (.01 level) improvement in both the multiple correlation and the improvement in prediction.

The consequence of all this significance, at least in the last step, is that the data do not meet the criterion for homogeneity of regression. This means that in interpreting the data many of the interactions added significantly to prediction in the regression equation and thus had to be considered. It also confirmed the original decision to use regression analysis. Heterogeneity of variance would have invalidated use of the analysis of covariance technique.

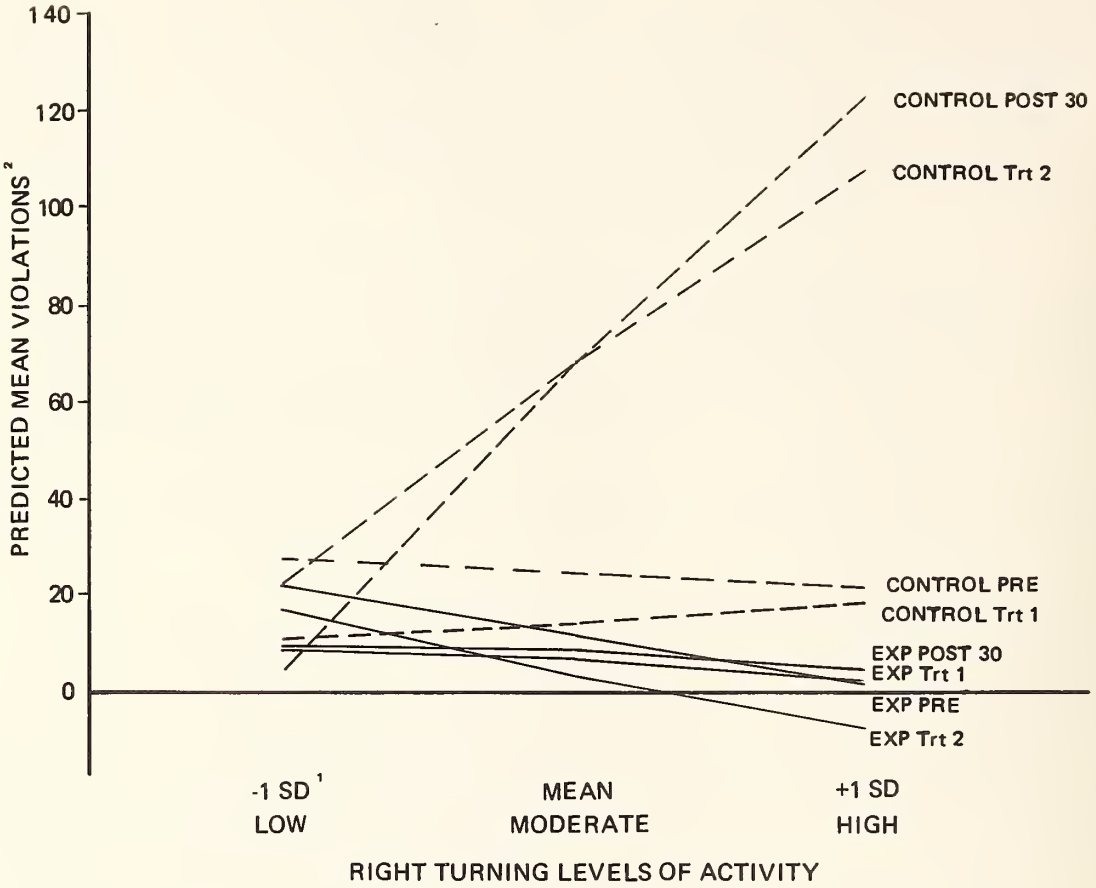
Examination of the data suggested that the source of the heterogeneity was the right turn volume. Another regression run was made. In the first step the four control variables, E/C groups, treatment periods, and time (a.m. or p.m.)/group/treatment period interactions were entered. All the right turn volume by group, treatment period, and time period interactions were entered in the second step. The multiple R of the regression equation for this solution was .71, significant beyond the .001 level ($F = 13.9$, 33/448 df). The R square, which indicates the percent of the variance in violations accounted for by the regression equation, was .50%. The improvement in prediction by adding these variables was significant beyond the .01 level ($F = 3.6$, 448/15 df).

Two more steps were added to the regression equation. One added adjoining lane traffic volume; the other added bus volume. Neither step significantly increased the predictive ability of the equation. This meant that these two variables had a constant effect across the other control variables. Thus, all the interactions of bus and adjoining lane volume with the experimental variables did not have to be considered.

The final regression equation still has 33 variables in it. The only way to visualize the various interactions is through graphical analysis. The 16 lines needed to create a graph were divided into two graphs, one representing the a.m. inbound rush on Post (E) and O'Farrell (C) Streets and the other representing the p.m. outbound rush on Sutter (E) and Geary (C) Streets.

Figure 15 shows the control and experimental groups for Post (E) and O'Farrell (C) Streets (a.m.). The graph shows the predicted mean violations for each of three levels of right turn volume. A predicted mean is the actual mean violations adjusted to account for the effects of the control variables (bus volume, traffic volume, right turn volume, a.m./p.m.). The reason for the right turn volume interaction with other variables is evident from the Control Post 30 and Control Trt. 2 lines diverging from the cluster of other entries.

For Post and O'Farrell Streets, the a.m. condition, are there any differences between treatments and groups? Looking at Figure 15 reveals that the mean violations on the experimental street are increasing less than on the control street as right turn volume increases. Closer examination shows only that the Treatment 2 (addition of the overhead signs) violations are consistently below the "before" or pre-treatment violation levels. The smaller number of violations for Treatment 1 (buffer zone) and the "30 day after" (Post 30) disappear with increasing right turn



Notes: 1. SD=Standard Deviation
2. Predicted mean SUL violations are adjusted via the regression equation to account for the four control variables.

Figure 15. Predicted mean violations for the a.m. SUL –San Francisco.

volume. Basically this has been an analysis of the before-after and after 30 day sequence of data. To take advantage of the control data, the relation of control and experimental data lines on Figure 16 must be considered.

Research conditions are ideal when control conditions do not vary over time, and start out in the "before" period at the same level as the experimental conditions. These conditions did not exist in this field study. Since the control conditions varied considerably over the four experimental periods, a way to visualize the relationship of control and experimental groups was needed.

Figure 17 provides a graph of the difference in predicted mean violations for the a.m. and p.m. streets at three levels of right turn volume. Regardless of actual level, control violations are represented at zero, and the differences between control and experimental violations are plotted. In all cases except two (see plots A and D), the experimental sites have lower violation rates than the control sites. One indication that treatments had an impact on violations would be if the difference in violations increased following the "before" condition. Figure 17 must be interpreted with a view to what changes took place.

For the a.m. streets in Figure 16, Treatment 1--the buffer zone--is closer to the control streets than in the "before" condition. The impact of new overhead signing appears to be quite large. While much of this difference is due to extensive differences in control street violations for the moderate and high right turn volume levels, experimental street violations are decreasing. Except at the lowest level of right turn volume, the same finding is evident for the "after 30 days" condition.

Mean predicted violations for the p.m. E/C pair of streets are shown in Figure 17. Examining the "before" to "after"

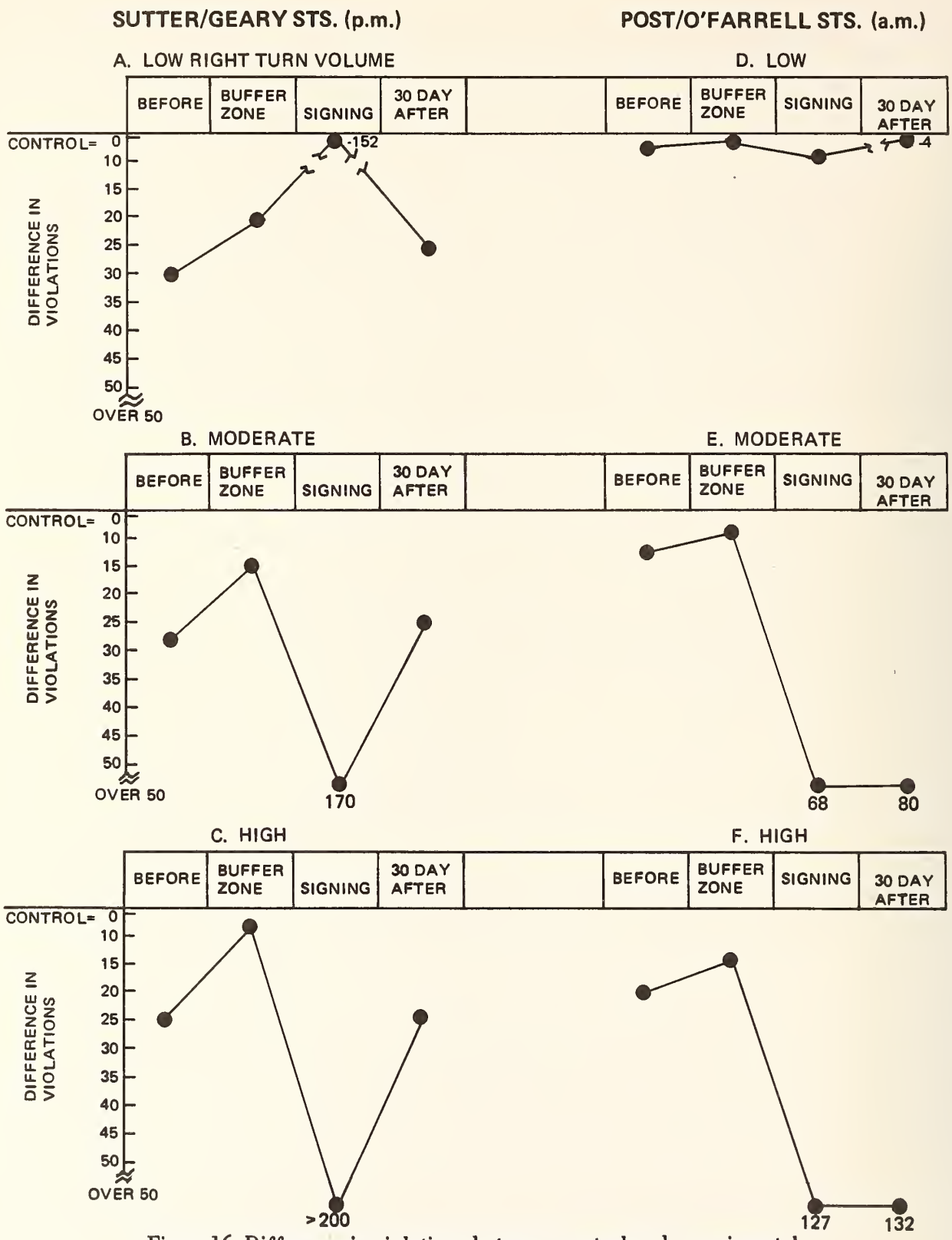


Figure 16. Difference in violations between control and experimental streets for three levels of right turn volume.

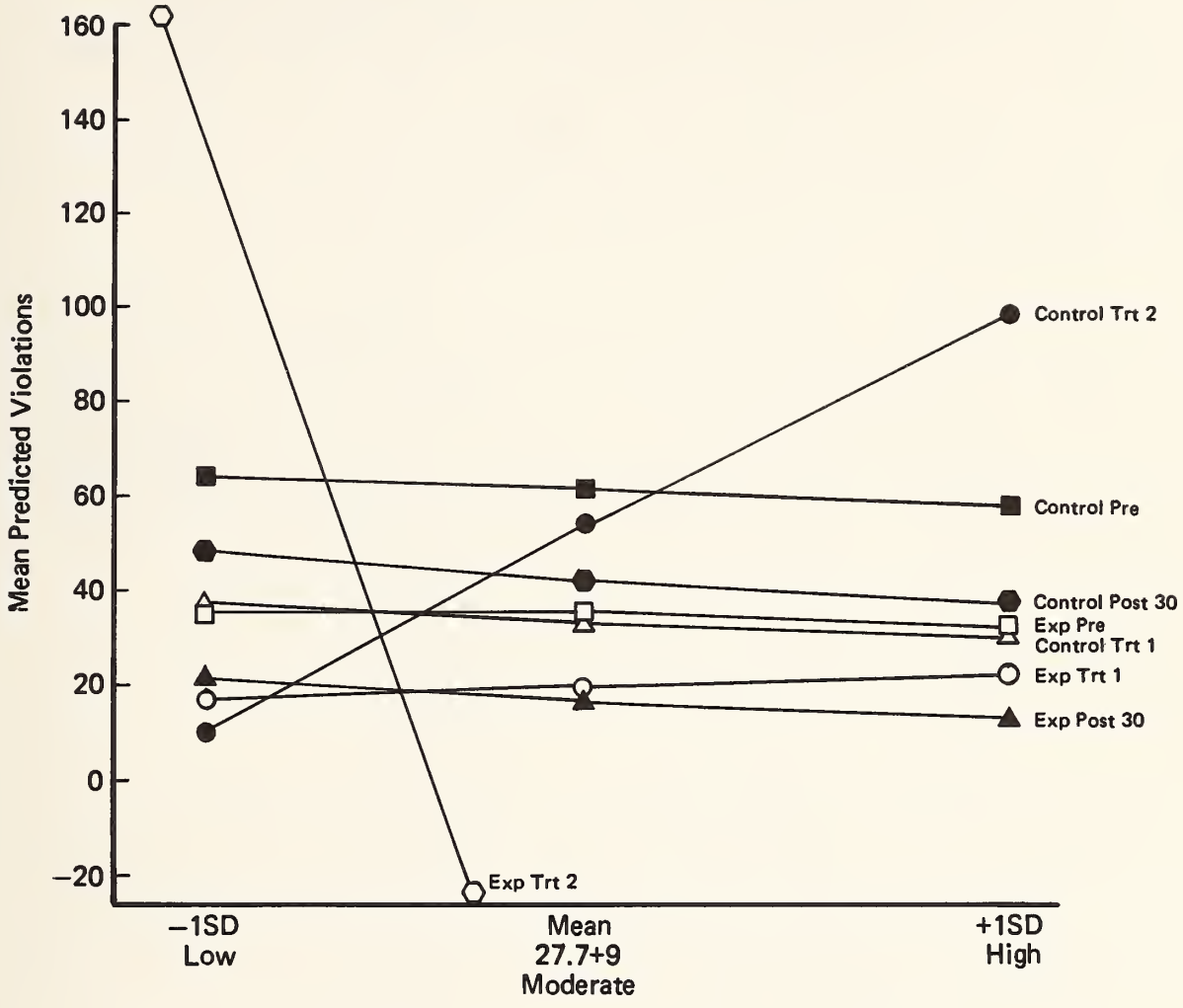


Figure 17. Predicted mean violations for the p.m. SUL–San Francisco.

dimension first indicates that all the treatment conditions have 25 to 50% fewer violations relative to the "before" condition in the experimental street. However, the control sites show similar changes. This is a clear demonstration of the danger in "before-after" experimental designs. The changes found in the experimental sites are also occurring on non-experimental streets. The question then becomes one of degree of change in the E and C data.

Figures 16A-C chart the differences in predicted mean violations between the E and C p.m. streets. Treatment 1, the buffer zone, is closer to the control street; i.e., the difference between the two is less than in the "before" period. When the overhead signing is added, the E/C difference greatly increases. Referring back to Figure 17, one finds widely diverging E and C data lines (Treatment 2). In the Post, or "30 day after," period, the E/C difference is almost identical to the "before" period difference.

Considering both "before-after" and E vs. C dimensions, there appears to be little effect from adding the buffer zone, a sizable effect apparent in the 25-50% reduction when overhead signs were added, and conflicting evidence of a lasting impact of the information system.

Turning now to the regression results, the regression program (1) calculates the multiple R and tests it for significance, (2) calculates the improvement in prediction by the addition of variables,, and tests it for significance, and (3) tests each variable (single and interactive) to determine its contribution to prediction on the regression equation. Table 6 gives the pertinent data.

Table 6

F-Test for Variables in the Final Solution of the Regression Equation - San Francisco (Dependent Variable = Violations)

	VARIABLE	B	F
E and C	GROUP	-0.7921+01	0.63
a.m. and p.m.	TIME	0.3105+02	17.27***
RIGHT TURNS	RT	-0.1230+00	1.10
VOLUME	BUSES	-0.1611+00	0.57
TRAFFIC	VOLUME	0.1204-01	0.73
BUFFER ZONE	TRT1	-0.1863+02	5.11**
OVERHEAD SIGNS	TRT2	0.8058+01	0.95
AFTER 30 DAYS	POST 30	-0.3224+01	0.23
	GRPTRT 1	0.4744+01	0.18
	GRPTRT 2	-0.2069+02	3.22**
	GRPOST 30	-0.1156+02	1.15
	TIMERT1	-0.1033+02	0.87
	TIMETRT2	-0.4746+02	18.87***
	TIMEPOST	-0.1501+02	2.75**
	TIMEGRP	-0.2113+02	4.01**
	TIMEGRT 1	0.4332+01	0.08
	TIMEGRT 2	0.9130+02	36.32***
	TIMEGRP 0	0.1511+02	1.18
	RTTIME	0.1032-01	0.00
	RTTRT 1	0.2069+00	2.02**
	RTTRT 2	0.1207+01	2.29**
	RTPOST	0.1667+01	4.58**
	RTTLT 1	-0.1769+00	1.09
	RTTLT 2	-0.4479-01	0.00
	RTT1P 0	-0.1678+01	2.40**
	RTGRP	-0.1933+00	0.59
	RTT1GRP	0.2479+00	0.88
	RTGRT 1	-0.4404-02	0.00
	RTGRT 2	-0.1231+01	1.69
	RTGRP 0	-0.1428+01	2.43**
	RTT1GRT 1	0.1406+00	0.20
	RTT1GRT 2	-0.6475+01	15.43***
	RTT1GRP 0	0.1397+01	1.37
	(CONSTANT)	0.3339	

** $\geq$.01

*** $\geq$.001 Note: Minus B indicates E lower than C when group involved.

Knowing E or C groups adds no significant information to the prediction equation when pooled across all other conditions. Of greater interest from a hypothesis testing point of view is the interaction of groups with the four treatment periods. There, the Treatment 2 variable adds significantly to the prediction of violations. This effect is clear in the graphical analysis.

Time of day is significant above the .0001 level, and several of the interactions containing the a.m./p.m. variable add considerably to prediction. It was this finding that led to a consideration of the a.m. and p.m. E/C site pairs separately in the graphical analysis. This implies that the treatments affect the E and C groups differently under different street conditions.

Right turn volume adds little predictive information by itself, but when interacting with treatments it is significant. (see RTxTRT 1, RTxTRT 2, RTxPost 30, and RTxTIxGRPxTRT 2 for examples.) Neither bus volume nor traffic volume adds significantly to the predictive equation. Treatment 1, buffer zone, adds predictive data, but only lumped across all groups. Since the only significant interaction occurs with right turn volume, there is little evidence, as suggested in Figures 15 and 17, that the buffer zone has a positive or negative impact on violations.

Treatment 2, overhead signs, is not significant, but as expected from the plots it is highly significant in all but two interactions. The actual magnitude of the effect is not clear because the data from the control streets diverge so widely. One way to estimate the magnitude is to determine a range of differences between the "before" and Treatment 2 period for the E streets. The a.m. condition provides a reasonable estimate of 25-40% improvement in SUL violations by the addition of overhead signs.

Thirty days after Treatment 2 installation, the effectiveness of the information system was in evidence on one experimental street but not on the other. Two of the significant interactions involving the Post 30 period include right turn volume and time. The unusually divergent Post 30 control data for the p.m. street (Figure 15) account for these interactions. These same data strongly impact the RT x Group x Post 30 interaction. Here the experimental control difference is significant, but only at two levels of RT and only on the a.m. streets. For reasons that are not evident in these data, effectiveness continued for the 30 days on one experimental street but not on the other.

Temporary Intrusions

The step-wise regression analysis was repeated with a different dependent variable. Temporary intrusions are vehicles weaving in and out of the SUL because of lane blockage, e.g., truck double-parked; and vehicles weaving into the SUL then turning into alleys, parking garages, etc.

Findings in this analysis were similar to the preceding one reported. Bus and adjoining lane volume contributed significantly to prediction, but the interactions with other variables were not significant ($F=1.05$ with 431/15 df and $F=.30$ with 417/14 df). Right turning volume significantly interacted with the experimental variables. The multiple R of this solution was .893. Thus R^2 or the amount of variance accounted for in the regression equation was 79.8%. This correlation is statistically significant beyond the .0001 levels, ($F=53.3$, 446/33 df).

Morning and afternoon control/experimental street pairs were different. Figures 18 and 19, respectively, show these results. Predicted violations, i.e., mean violations adjusted to account for the influence of experimental and covariant factors, are

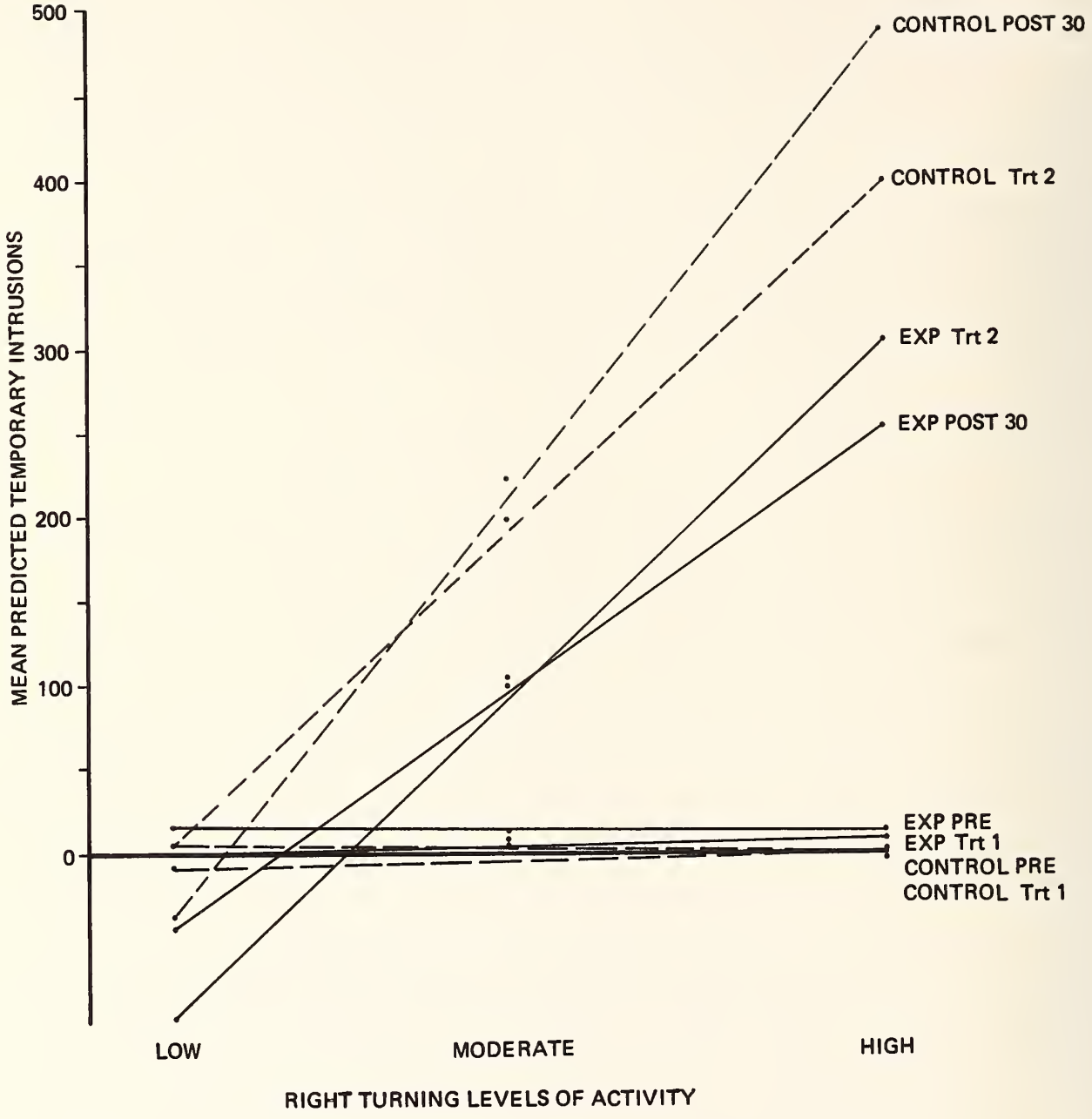


Figure 18. Predicted mean levels of temporary intrusions in the a.m. (Post and O'Farrell Streets)—San Francisco.

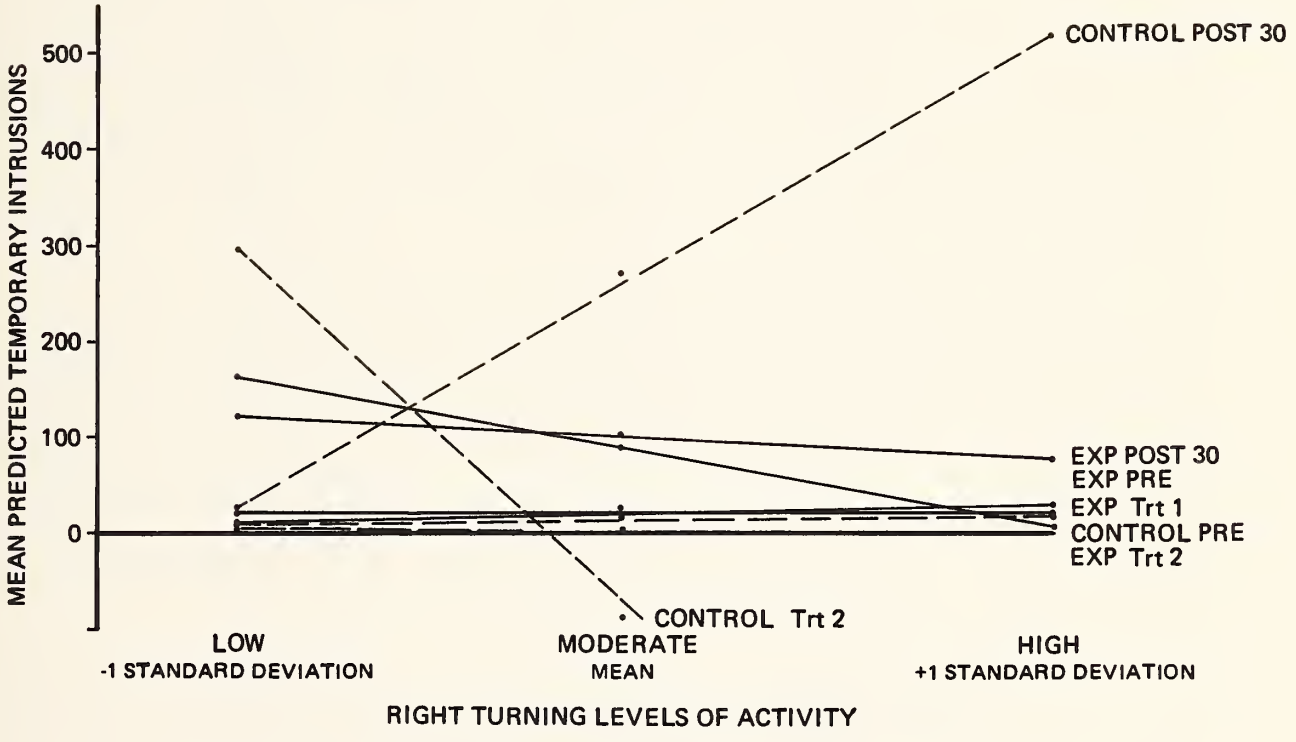


Figure 19. Predicted mean levels of temporary intrusions in the p.m. (Sutter and Geary Streets)—San Francisco.

illustrated. Since right turning volume interacts with the experimental variables, the plots include three levels of right turn volume.

Determining the effect of the various treatments is accomplished by looking at the factors and interactions in Table 7. Primary interest is with interactions involving experimental and control groups and treatments (Trt 1=buffer zone, Trt 2=overhead signing added, and Post 30=after 30 day acclimation). Neither by itself nor in any interaction does the addition of Treatment 1 data (after buffer zone installation) contribute significantly to the prediction of temporary intrusions into the SUL.

On the other hand, addition of overhead signing (Treatment 2) makes a significant contribution to the prediction of temporary intrusions. More importantly the group (E vs. C) by Treatment 2 interaction is significant beyond the .001 level. Thus intrusions are less for the experimental than the control group. Several other interactions involving the overhead sign treatment are also significant.

The "30 day after" data follows a similar pattern. However, fewer interactions are significant. The a.m. vs. p.m. by Post 30 interaction suggests different effects on the two site pairs. Referring to Figures 18 and 18 shows treatment effect was much stronger on Geary Street (p.m.) than on Post Street (a.m.).

In summary, there was no indication that the buffer zone itself had an effect on temporary intrusions or weaving. When signs were shifted from shoulder to overhead mounting there was a statistically significant shift to fewer intrusions on the experimental streets compared to the control streets. Thirty

Table 7

F-test for Variables in the Final Solution of the Regression Equation - San Francisco (Dependent Variable = Temporary Intrusions)

Variables in the Equation

VARIABLE	B	F
Group	0.2252+02	1.97
Time	0.1021+02	0.71
RT	0.8114-01	0.18
Buses	-0.4519+00	1.74
Volume	0.4300-01	3.59
Trt 1	0.1489+02	1.25
Trt 2	0.8073+02	36.69***
Post 30	0.5945+02	30.16**
GrpTrt 1	-0.2334+02	1.70
GrpTrt 2	-0.9128+02	24.12***
GrPost 30	-0.6567+02	14.27***
TimeTrt 1	-0.1446+01	0.66
TimeTrt 2	0.7651+02	18.86***
TimePost	0.4591+02	9.91***
TimeGrp	-0.1320+02	0.60
TimeGrt 1	0.2315+02	0.88
TimeGrt 2	0.5854+02	5.74
TimeGrPo	0.6767+02	9.09***
RTTime	-0.1070-01	0.00
RTTrt 1	-0.1813+00	0.59
RTTrt 2	0.4489+01	12.20***
RTpost	0.6157+01	24.05***
RTTiT 1	0.1032+00	0.14
RTTiT 2	-0.1368+02	63.19***
RTTiPo	-0.3239-00	0.03
RTGrp	-0.9177-01	0.05
RTTiGrp	0.3155-01	0.00
RTGrT 1	0.2615+01	0.32
RTGrT 2	0.2387+00	0.02
RTGrPo	-0.2621+01	3.15
RTTiGrT 1	-0.1996+00	0.16
RTTiGRT 2	0.7061+01	7.05**
RTTiGrPo	-0.3889+01	4.11
(Constant)	-0.1372+02	

** = $\geq$.01

*** = $\geq$.001

df = 1 and 395 (.01 level = 6.70)

days later there were still significantly fewer intrusions on the experimental streets, particularly during the p.m. rush hour. Thus the information system was effective in reducing temporary intrusions. The major change agent, however, appeared to be the overhead signing. These effects were strongest in the presence of moderate and high levels of right turn activity.

Driver Perceptions

Drivers were queried while stopped at red lights during the "before" and again during the "after 30 day acclimation" (Post 30) data collection period. The "before" and "after" questions were slightly different, as shown in Figure 5. The sample sizes achieved are given in Table 8.

Table 8

Sample Size of Driver Queries - San Francisco

		Before	Post 30
Experimental Streets	Thru Devices	112	321
	Violators	73	151
Control Streets	Thru Drivers	103	170
	Violators	40	58
	Total	328	700

The results are discussed as answers to each of the questions. The complete data are shown in Appendix C.

"Before" Data

1. Are you aware of a special use for any lane on this street during rush hour? Violators were more aware of the SUL (75-77% yes, 23-25% no) than through or non-violator drivers (61-63% yes, 37-39% no) on all streets. The control and experimental streets were similar with 63 and 68 yeses, respectively.

2. Which lane is it and who can use it? Only those answering "yes" to question 1 were asked this question. Being aware of the SUL was synonymous with knowing the rules of use, as 99% answered correctly. A major function of signing and delineation appears to be to create awareness. Once established, drivers apparently make the effort to find out what is happening.

2a. About how often do you drive by here? This was asked to determine if those unaware (responded "no" to question 1) of the SUL were primarily unfamiliar with the street. This was the case for violators more than through drivers:

	Violators	Through
Drives street every day	17%	32%
Drives street at least once a week	29%	24%
Drives street less than once a week	54%	44%

3. Do you think the SUL is a good idea? Willingness to violate the SUL may be influenced by acceptance of the operation. Drivers who are vehemently against the SUL may be quite willing to violate it, particularly where enforcement is minimal. The difference between through and violating drivers was quite small, as shown in Table 9. However, only 55% of those interviewed agreed the SUL was

a good idea. This suggests a more extensive or at least continuing public education and public relations effort may be beneficial for SUL operations. Table 10 summarizes the content analysis of comments received about the SUL. These comments suggest the type of information or data and perhaps review of operating practices which could be used in dialogue with the driving public.

Table 9

Driver Reactions to the SUL

	Violators	Through Drivers	Total
SUL a good idea?			
Yes	55/48%	129/37%	184/55%
No	45/39%	81/37%	126/38%
Undecided	14/13%	11/5%	25/7%
Total	114	221	335

"After" Data. Since a project concern was driver perception of the information system, the "after" questions focused more directly on signs and markings.

1. Did you see any information about the use of the right lane on this street? Significantly more of the drivers on the experimental streets saw the SUL information system ($X^2 = 7.32$, 4 df, $p < .01$). While 43% compared to 32% was statistically significant, it is still a low overall percentage of drivers. Ideally every driver should have seen the SUL signing. However, the information analysis (Volume II) indicates that only those in the lane adjacent to the SUL who might turn right, park, or use it to go around congestion need to know about SUL location and rules. Since drivers from all lanes were queried, the findings may be overly conservative.

Table 10

Summary of Content Analysis of Driver Opinions of SUL

Response Category	Typical Comments
Unqualified	
Yes	- the idea is good in theory and practice
Yes	- the idea is good in theory but not in practice • Not suited for this corridor • Buses don't stay in it and out of my way • It should only operate during peak hours not 24 • It should include other HOVs
I don't know	- I guess so • I'm from out of town • Signs and markings inadequate • I just don't know how it works • I never thought about it/I don't care • I don't really know if it's justified
No	- the idea is no good because it doesn't work • Really creates more congestion/ clogs up things • Buses don't need it and they don't use it right • Gets in the way of right turns
No	- I am opposed to the idea • There are more cars than buses • We just don't need it--it's a "dumb" idea

As in the "before" condition, violators saw the signs/markings (E=49%, C=46.5%) more than the through drivers (E=40.2%, C=27%). It appears that close to one-half of the violators are conscious of their actions. In all likelihood countermeasures more positive than passive signs and paint, e.g., tube cones, active enforcement, public education, must supplement the information system if violations are to be reduced further.

From a driver's point of view, the experimental signing and buffer zone markings resulted in improved information system awareness.

2 and 3. What did you see and what did it tell you?
Drivers who hadn't seen the signs or markings were shown a picture so all could respond to these questions. There was not a statistically significant difference between the E and C groups. Violators understood or described the signs/markings better than general lane drivers (74 vs. 54%), again suggesting that proximity to the SUL is a factor in awareness. This finding supports the general notion of larger SUL sign sizes in addition to overhead placement.

Conclusions

The effect of SUL sign placement (overhead vs. shoulder) and a buffer zone (◇◇) were studied in a "before-after" experimental design with control groups. The buffer zone treatment was applied to two one-way streets having 24-hour bus only SULs on downtown San Francisco in- and outbound arterials. Two similar streets were not changed. Following data collection, new SUL signs were mounted overhead from trolly support cables. Data were collected again and after a 30-day acclimation period.

Three null hypotheses were tested.

H_1: There will be no difference between the experimental signing and delineation system and the existing system.

Conclusion:

The experimental information system resulted in a moderate (25-40%) reduction in violations and in temporary intrusions (double parking and weaving). This effect continued on one of the experimental streets but diminished on the other during the 30 day acclimation period. The information system treatments did improve driver perception by at least 10%.

H_2: The buffer zone will not change violation rates compared to the solid white line.

Conclusion:

The buffer zone alone did not reduce or increase violations or temporary intrusions into the SUL.

H_3: Overhead signing will have no effect on violation rates compared to shoulder mounted signs.

Conclusions:

The overhead mounting and redesigned signs were the prime factor in the 25-40% reduction in violations and intrusions. The higher mounting also contributed to drivers in other parts of the street becoming more aware of the SUL.

CHAPTER 4

FIELD STUDY #3: FREEWAY CONCURRENT FLOW BUS/CARPOOL LANE DELINEATION AND SIGNING

(Hawaii)

Purpose

A question of particular concern had been how to mark or delineate a concurrent flow bus/carpool lane from the general driving lanes. The delineation could not include a physical barricade since the SUL lanes became general lanes during non-rush hours. To fill this need, buffer zone designs were created and laboratory and closed-field tested. However, these totally new delineation designs called for operational testing. San Francisco and Rochester filled the need for arterial roadway testing, and this study tested the following null hypotheses in the freeway setting.

- Buffer zone delineation in concert with a fully fuctional signing system will not effect SUL violations.
- There will be no differences in violations between alternative buffer zone designs.
- Neither speed in SUL nor adjoining lanes will be affected by addition of buffer zone delineation.

Experimental Design

A before-after with matched control paradigm was possible in Hawaii. The Moanalua Freeway has part-time concurrent flow bus/carpool lanes in both directions, as does the H-1 Freeway. Both run between the Pearl Harbor area and Honolulu so they serve the same population centers. The SUL operating rules, signing, and delineation were the same.

The original timing of the experimental plan was severely disrupted by the onset of a three-month public workers strike the day "before" data collection began. This meant the buffer zone installation had to be delayed until the strike was resolved. Four days of "before" data were collected in October, a buffer zone installed in late January, and two days of "after" data collected. Two weeks later the buffer zone design was modified and another two days of "after" data gathered. Then, 30 days elapsed and two days of "after acclimation" data were collected.

Site Description and Information Treatments

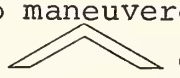
H-1 is an eight-lane interstate highway marked and signed with the median (inside) lanes as part-time concurrent flow bus/carpool lanes. Full-width (12 ft.) shoulders were next to the SULs. Lane delineation was provided by dashes made up of clusters of four Bot's dots. Between clusters was an RPM. Approach, entrance, through, and exit SUL signing was in place. Mid-lane diamonds were placed every 600 to 1,000 feet. Figure 20 depicts the various signs found on the H-1 and Moanalua Freeways. The data collection vantage points are depicted in Figure 21. Two other features of interest can be seen in Figure 21A. The Moanalua Freeway SUL had a faded solid white line next to the RPMs. The Moanalua Freeway was in all other respects an older but extremely similar highway. The visible line perpendicular to the lane lines was one of two lines used in making manual speed measurements.

Preliminary volume counts indicated hourly SUL and general lane traffic volume lower on H-1, but violation rate higher, than on the Moanalula Freeway. Thus, while these two were highly similar physically they were not as closely matched operationally. However, note that this was the only concurrent flow freeway bus lane in the entire country suitable at that time for the required field test.

A buffer zone, as depicted in Figure 22, was installed on the inbound, a.m., SUL of H-1. In these pictures the markings for an outbound SUL are evident. During the public workers strike in Hawaii (after the "before" data was collected) the outbound SUL was discontinued. Enforcement ceased and some of the signs were removed. Therefore it was no longer available as an experimental site. After the buffer zone was installed, Hawaii DOT and police decided the solid white line should mean "do not cross" and asked BioTechnology to modify their second information treatment. So instead of adding or filling in diamonds within the buffer zone, two weeks were spent sanding part of the delineation away to create a dashed line buffer zone. The result can be seen in Figure 23.

Dimensions of the buffer zone were:

- 20" width
- 3" stroke width
- 14" x 56" diamonds (4:1 ratio)
- Outline diamonds (not solid white)
- Diamonds spaced 80' center to center.

Application here, as in San Francisco, was by a three-man crew. One person measured and worked the hand paint sprayer, while the other two maneuvered a 24" x 60" piece of plywood with a half diamond  cut in it. Application was never more than two minutes per diamond plus time to move between diamonds. The two solid white lines had been previously painted by a regular truck-mounted line applicator.

Enforcement on the Moanalula and H-1 Freeways was under the direction of one police barracks and was comparable for the two facilities. Twice during a three-day data collection

A. Approach sign.

B. Entrance sign.

Figure 20. SUL signing and delineation, before condition – Hawaii.

C. Entrance and through signs.

D. Carpool definition sign and mid-lane diamond.

Figure 20. (Continued)

E. Through zone sign.

F. End of SUL sign.

Figure 20. (Continued)

A. Inbound Moanalua Freeway.

B. Inbound H-1 Freeway.

Figure 21. Data collection vantage points – Hawaii.

Figure 22. Two views of the buffer zone on H-1 –Hawaii.

Figure 23. Dashed buffer zone of H-1 –Hawaii.

period a squad of two or three motorcycle police would specifically "work" the SUL. Time, day of week, and length of stay were rotated to give a random appearance to motorists. This level of enforcement was maintained throughout the study's duration.

Methods and Measures

Time-lapse film was used to record traffic movement on the control and experimental sites, e.g., volume. Counting the number of people in a car could not be done from film, so these were manually observed and called into a tape recorder. A clock was placed in the field of view of the time-lapse camera and time was frequently called into the tape recorder along with violation status and a brief vehicle description, e.g., white Pinto wagon. Thus if there was a need, each violator could be found on the film by indexing time. Also, violations and volume per unit of time, 5 minutes maximum resolution, was available. The major reason violations cannot be taken off film is that it is difficult to see rear seat adult occupants and even harder to see children anywhere in the car.* Filming was done over the two-hour a.m. rush, 6:30-8:30, which peaked between 7-7:30 a.m. Speed data were collected intermittently, i.e., collected for 15 minutes, then film and violation data were gathered for 15 minutes, and so on for two hours.

The speed data collection technique was manual and was based on measuring the time it took a vehicle to travel between two points. Lines, 200 feet apart, were painted perpendicular to the flow of traffic in the SUL and adjoining lane. An observer, always standing at the same place, started a digital stopwatch as

*One reason the Hawaii SULs are heavily used is that families drive to Honolulu, take children to school or day care centers and return home together at night. Thus the carpool criterion of 3 riders is achieved in many vehicles but often riders are lying down, playing on the floor, or sitting on an adult's lap.

the front tires of a vehicle touched the first line then stopped the watch and recorded the time when the same front wheels touched the second line.

Since there was ample opportunity for sample selection bias, (obviously not every car could be timed) a random sampling procedure was used. A beeper in the observer's pocket sounded every ten seconds. The next vehicle to be timed was that which first came to the timing line after a beep. Timing alternated from lane to lane; SUL to adjoining and back.

A major question with this technique is reliability. Prior to collecting any data, all combinations, in pairs, of field observers timed the same vehicles; twenty per pair. Correlation coefficients for each pair of observers were calculated and these ranged from r= .91 to .98. The pairs with highest reliability worked together and always were assigned the same site. This process was repeated prior to each of the four data collection periods. The very high reliabilities indicate this method of speed measurement is probably within or very close to the reliability of more instrumented methods, e.g., radar, TES.

Accuracy of speed measurement was found to be in the ±10% range of the TES or radar by Berger and Hanscom.* Since the major concern of this study was speed differentials, not absolute speed, such accuracy was more than sufficient given the very high and more critical reliability.

In summary, the above procedures resulted in speed data by time period for the SUL and adjoining lane, violation data for the SUL, and volume data by vehicle type for the SUL and adjoining lane. A minimum of two and maximum of four 2-hour data gathering sessions

*Hanscom, F.R., & Berger, W.G. Motorist response to highway guide signing. Volume 1. Field evaluation of measures (Final Report of Project 3-21). Washington, D.C.: Transportation Research Board, January 1976.

were held for each data collection period. This translated into two to four hours of volume and violation data; a similar amount of speed data was collected. The entire SUL operating time was covered by all measures on a sampling basis for at least two days per data collection period.

Weaving was not directly measured in that the portion of SUL observed was relatively short and not necessarily indicative of overall SUL performance. While collecting the data it became clear that weaving location followed congestion, i.e., as traffic slowed down or stopped in a particular lane weaving to avoid the back-up increased. Since the area of congestion moved up and down the Moanalula past the data collection point rather quickly, but much less frequently past the H-1 vantage point, comparable data could not be collected within project resources.

Results and Discussion

The step-wise regression analysis was applied to the data of this study. Number of SUL violation--cars with less than three occupants--served as the dependent variable. The control variables or covariants were SUL speed, adjacent lane speed, SUL volume, and adjoining lane volume.

The speed measures and SUL volume correlated so highly, $r = -.77$ to $-.79$, that independently they added little to the prediction of violations. Also they correlated very little with violations, $r = -.16$ and $-.17$. Adjacent lane volume correlated significantly with violation, $r = .54$; therefore playing a major role in the final regression equation. Volume also varied by time, a.m. or p.m., and hour, 1st or 2nd; these later variables added little to the regression equation and were not used in the final solution.

The factors were added to the regression equation in four steps. By the third step, adjacent lane volume, the different data collection periods (Treatment 1, Post 30) and group (E and C) were entered in the equation. The multiple R of .69 was highly significant. On the fourth step, the group by treatment interactions were entered but did not result in a significant improvement in prediction. This indicates that violations did not vary differentially for the control and experimental groups as a result of the buffer zones. Figure 24 shows that violations decreased about the same amount at the control and experimental site.

In considering that a statistical difference was not achieved, several mitigating factors should be noted. First, the two sites while physically similar were operationally somewhat disparate. Speed data for the two sites, shown in Figure 25, reveal the wider variation in speed and, hence, level of service found on the control site. If violating the SUL is motivated by driver desire to get around congestion, then the lower the level of service, the more likely violations will increase. The more violations occurring, the more potential for showing an effect of a countermeasure. Clearly the experimental site did not suffer decreases in level of service, and the number and rate of violations was approximately 32% lower than the control site. In spite of this, violations were reduced proportionately more at the E rather than at the C site. Table 11 illustrates this point.

Table 11

Proportionate Reduction in Violations - Hawaii

	Control Site		Experimental Site	
	Adjusted Mean Violations	Percent Reduction	Adjusted Mean Violations	Percent Reduction
Before	28.4	19.8	19.3	29.1
Trt. 1	22.8	28.4	13.7	47.3
Trt. 2	16.3		7.2	

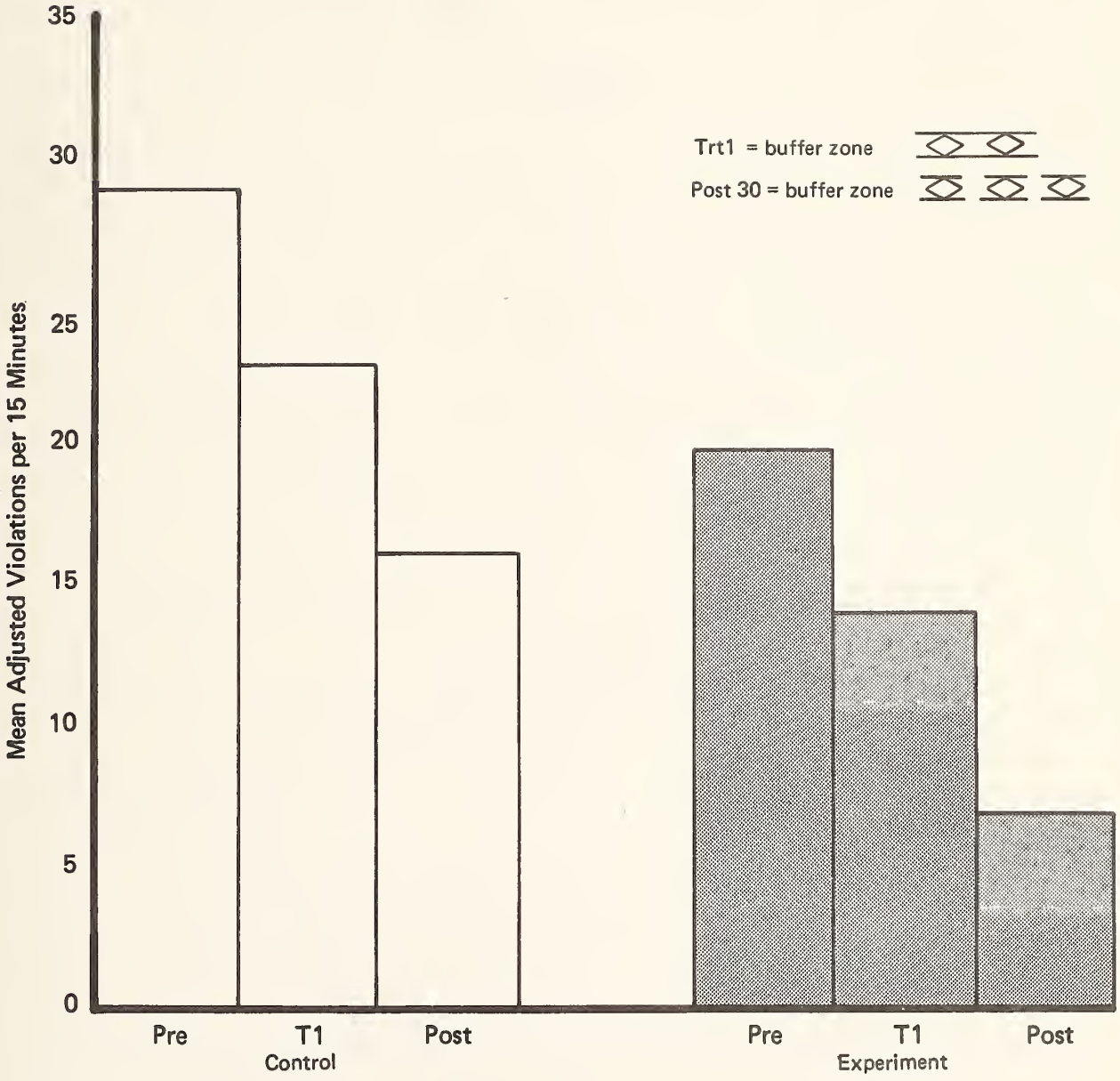


Figure 24. Predicted mean violations for the concurrent flow freeway study – Hawaii.

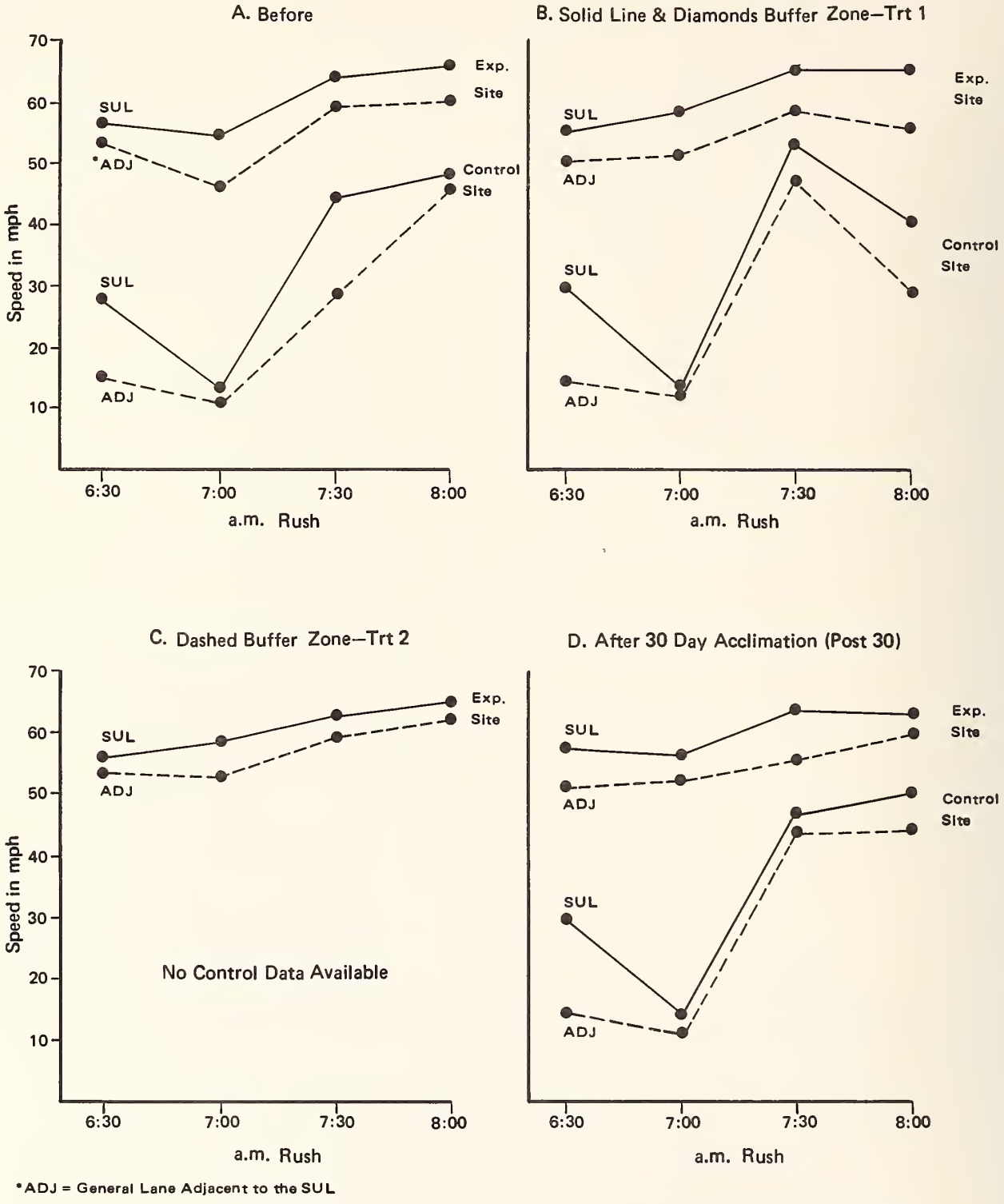


Figure 25. Speed results for the experimental and control sites – Hawaii.

This type of analysis suggests the buffer zones did have some effect on driver SUL violation behavior. In a situation where congestion is more severe, a buffer zone may not provide sufficient impetus to deter violators; however, that test could not be performed at this site.

Conclusions

Three hypotheses concerning the effect of SUL buffer zone delineation on freeway bus/carpool lanes were tested with a before-after experiment using control and experimental sites. The step-wise regression analysis indicated volume was most strongly related to SUL violation behavior and that the buffer zones had minimal impact on violations. Because of the operational differences between the E (lower violation rates, higher levels of service) and C (higher violations, lower levels of service) sites, an analysis of proportional change was done. This suggested the solid line and dashed buffer zones had a positive impact.

Specifically in terms of the hypotheses for this study:

H_1: Buffer zone delineation in concert with a fully functional signing system will not effect SUL violations.

Conclusions:

In a freeway situation the effect is positive but minimal, probably producing not more than a 10% reduction in violations.

H_2: There will be no differences in violations between alternative buffer zone designs.

Conclusions:

This hypothesis was not rejected by the data.

H_3: Neither speed in SUL nor adjoining lanes will be affected by addition of buffer zone delineation.

Conclusions:

This hypothesis was not rejected by the data.

CHAPTER 5

FIELD STUDY #4: FIELD TEST OF ALTERNATIVE INFORMATION PRESENTATION TECHNIQUES ON ARTERIAL BUS LANES

(Baltimore, MD)

Purpose

Earlier laboratory research (Volume II) clearly suggested that standard-word formats were preferable to the various symbol or symbol + word formats in either a horizontal or vertical sign element alignment. The results also showed that splitting the considerable amount of information required on a concurrent flow bus lane, especially with part-time operation, may result in more complete and accurate sign reading. As additional numbers of vehicles were mentioned on the sign this advantage diminished. In other words, there was a question as to which information presentation scheme should be used in an arterial setting. The Baltimore, Maryland, site allowed a test of the split and repeated signing techniques. It further offered an opportunity to test the impact of extensive upgrading from a minimal SUL information system to the full MUTCD standard using the experimental signing of this project.

There was no signing in advance of the Baltimore SULs. Here was the only opportunity among the field studies to specifically examine the effect, particularly in terms of weaving, of advance signs.

The hypotheses tested were:

- There is no difference reflected in driver performance between split or chunked signing and a repeated signing technique on an arterial SUL.

- There is no difference in driver behavior between a minimal SUL signing system and a MUTCD standard SUL system.
- Advance signing does not change driver weaving behavior at the entrance to an SUL.

Experimental Design

The control-experimental with before and after measures paradigm was possible in Baltimore. Charles and Fayette Streets had the experimental SULs and Calvert Street served as the control. "Before" data were collected for three days (Tuesday, Wednesday, Thursday) in May, the treatments were applied, and "after" data collected for three similar days later in May. Thirty days passed and "after acclimation" data were taken the third week in June for three like days.

Site Description and Information Treatments

All three streets are part of the computer controlled signal system in downtown Baltimore. Each serves as a major outbound evening rush hour corridor for buses and cars. The SULs all have similar operation and signing. The right curb lane is reserved for buses and right turn vehicles from 3 to 6:30 p.m. Monday through Saturday. Calvert and Charles Streets are five lanes wide with no parking allowed during SUL operation. Fayette is also a one-way street but has only three lanes with no parking during SUL operation. Figure 26 illustrates the three streets. The SULs ran well beyond the circled parts, which represent the areas where data were taken. The map shows the jog in Charles Street around the Washington Monument. The jog was the advance area for the SUL and was the site of one advance zone weaving study.

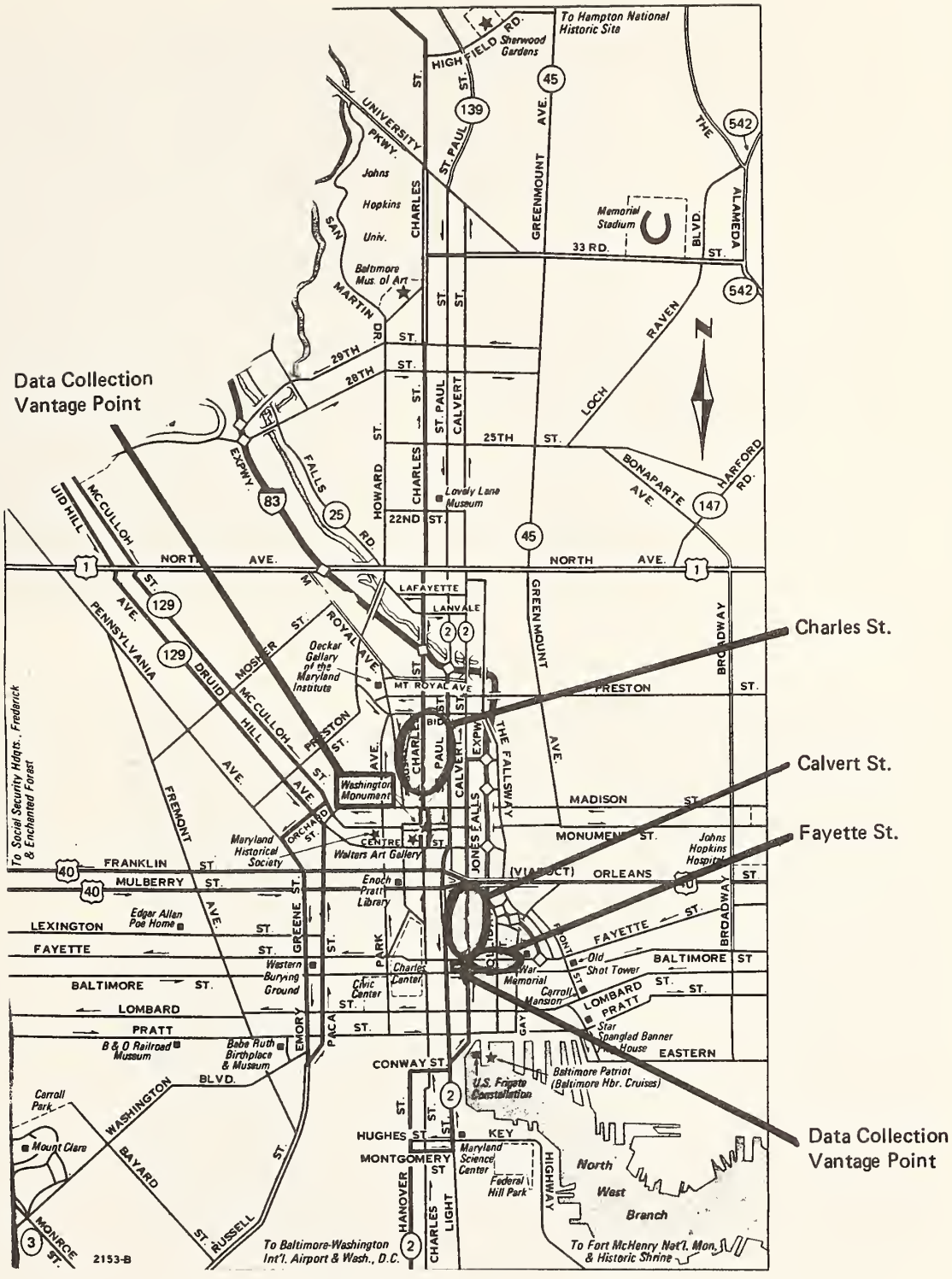


Figure 26. Map of Baltimore field study sites.

The advance zone to the Fayette Street SUL was not a jog, but was a constriction with a parking lane dropped and the through lanes reduced from 12 feet to 10 feet wide. The beginning of the Calvert Street SUL was also preceded by a jog around a monument similar to the Charles Street situation.

Figure 27A through D is a sequence of pictures showing the original signing and marking on Charles Street. What is not obvious from these pictures is that many signs were badly worn and missing. Of the four blocks used experimentally, only two had a sign remaining.

Figure 28A through D is a similar sequence of pictures illustrating the "before" condition of Fayette Street. Figures 28C and D also show the 3rd floor windows in the building "dead ahead" used as a data collection vantage point.

Figure 29 is a view from the same vantage point picturing the entire Calvert Street SUL used for data collection. The signs here were identical to, and as infrequent as, the Charles and Fayette Street signs. The solid white line is virtually worn away and indistinguishable in any photos.

Enforcement remained a constant throughout this study. There had been no active enforcement of the SUL for at least two years prior to this project and that did not change during the course of the study.

The experimental sign design was the same for both streets. The only variation was the amount of information on each sign. As Figure 30B illustrates, the Charles Street signs split the information and presented the two signs in rapid succession along

A. In advance of SUL.

B. Advance jog and entrance to SUL.

Figure 27. "Before" signing and marking of Charles St. SUL –Baltimore.

C. Worn solid white line delineation.

D. Sample of original SUL signing.

Figure 27. (Continued)

A. Approaching the start of the SUL.

B. Entrance signing.

Figure 28. "Before" signing and marking of Fayette St. SUL—Baltimore.

C. Solid white line delineating SUL.

D. Typical SUL sign.

Figure 28. (Continued)

Figure 29. A view of Calvert Street from the data collection vantage point.

A. Advance or approach zone sign.

B. Detail of second sign in each pair.

C. First and second sign plus diamond as installed.

Figure 30. Information treatment on Charles St. – split presentation.

with the mid-lane diamond. There were two signs and diamonds per block and two advance warning signs. Advance and end signs were 30" wide and 30" high; the other signs were 30" wide by 40" high. Pavement diamonds maintained the 3:1 length-to-width ratio used in the other field studies. In Baltimore 9' x 3' diamonds with a 6" stroke width were created from reflective lane striping tape. The first five of the eighteen blocks of the SUL were treated. The reason for treating five blocks when only four were used in data collection was to assure that drivers in block four did not see a sudden change in signing and delineation and react to that transition within the zone of interest.

Fayette Street signing and diamonds are shown in Exhibit 31. Sign and diamond dimensions are identical to Charles Street treatments. There is an added information element, 7-9 AM, not required on the Charles Street signs. Thus the letter sizes are smaller (4- and 3-inch, Series D) compared to the all 4-inch, Series D letters on the Charles Street signs. Three signs and four diamonds were used in the two block SUL.

Design concepts incorporated in these signs include:

- Defining the diamond symbol in the approach and entrance zones, then using the symbols on all signs. However, sign messages have meaning even if the diamond is not clearly understood.
- Use of the symbol embedded in black becomes part of the symbology and adds a unique visual characteristic necessary to distinguish the SUL from all other regulatory (black and white) signs.
- Symbol is paired on the pavement and sign.
- Information is provided in all information zones: approach entrance, through, and exit.

A. Approach zone sign.

B. Through zone sign and diamond.

C. End of SUL sign.

Figure 31. Signing and delineation on Fayette St. –Baltimore.

- All required user information is presented past each major point of entry to the SUL, e.g., cross streets.
- Standard-word format, but larger lettering than typically found on arterial SUL signs for improved conspicuity and legibility.
- Vertical alignment, as opposed to arterial SUL signs.

Methods and Measures

Time-lapse film was used to capture violation rates. The film was exposed at two frames per second, two hours per day for three days per data collection period, and was scored using the categories explained in earlier chapters. Bus volume, right turn volume and adjacent lane traffic volumes were also retrieved from the films. While field investigators were filming, they also timed bus progress from the beginning of the SUL to the end of the data collection section. Only one digital stopwatch was used, so a sampling procedure whereby the next bus entering the SUL after a beeper (which sounded every ten seconds) assured no bias.

A separate field investigator manually observed and scored weaving behavior in the approach to the SULs at Charles and Fayette Streets. The block before the SUL began was designated the approach zone. In the "before" data collection period, the number of vehicles weaving into or out of the curb lane (which would become the SUL) were counted. Each block was divided into three zones and marked so drivers were unaware of any unique divisions. The type of weave and location were noted and entered on a form. The same procedure was followed once the advance signing was installed.

The final part of this field effort was the drive-through study. In the other studies driver awareness was tapped, but in-depth questioning and probing of drivers was not feasible in the 20-30 seconds available. Therefore, a sample of drivers was paid to drive a BioTechnology-provided vehicle through one of the experimental streets and the control street (Calvert). An experimenter rode along recording weaves and violations of the SUL, and noted comments. At the end of the drive a series of questions was asked the driver covering:

- familiarity with the streets
- recognition of markings seen (driver was given a panel of pictures with markings along the route plus distractors)
- meaning of markings (diamonds)
- meaning of SUL signs
- certainty of meaning
- rating of signs and markings as information conveyors
- suggestions for improving signs
- demographic characteristics.

If the driver violated the SUL during the drive, supplemental questions were asked covering:

- opinion of SULs
- condition of SUL use
- importance of time
- general frequency of SUL violation among drivers.

Appendix B has a sample of the questionnaire.

Subjects were recruited via newspaper ads. The sample of 48 drivers was stratified into:

Route	A=24				B=24			
Sex	M=12		F=12		M=12		F=12	
Rush hour or not	R=6	NR=6	R=6	NR=6	R=6	NR=6	R=6	NR=6
Age 16-24	2	2	2	2	2	2	2	2
25-55	2	2	2	2	2	2	2	2
56+	2	2	2	2	2	2	2	2

Each driver received $20 for 35-45 minutes of participation. The stratification plan was achieved as planned.

Results and Discussion

There were four dependent measures used in the Baltimore study, and the results for each are discussed separately.

SUL Violations

Figure 32 depicts the predicted mean violations after adjustment to account for the significant covariants--adjoining lane and bus volume. Over time, violations increased at the control street at the same time they decreased in the presence of the repeated signing treatment (Experiment 2 group), and they initially decreased then increased for the split or chunked information treatment.

The step-wise regression indicated statistically that adjacent lane and bus volumes significantly relate to violation, as do the data collection periods (before, Treatment 1, Post 30) and the experiment/control groups. However, the Experiment 1

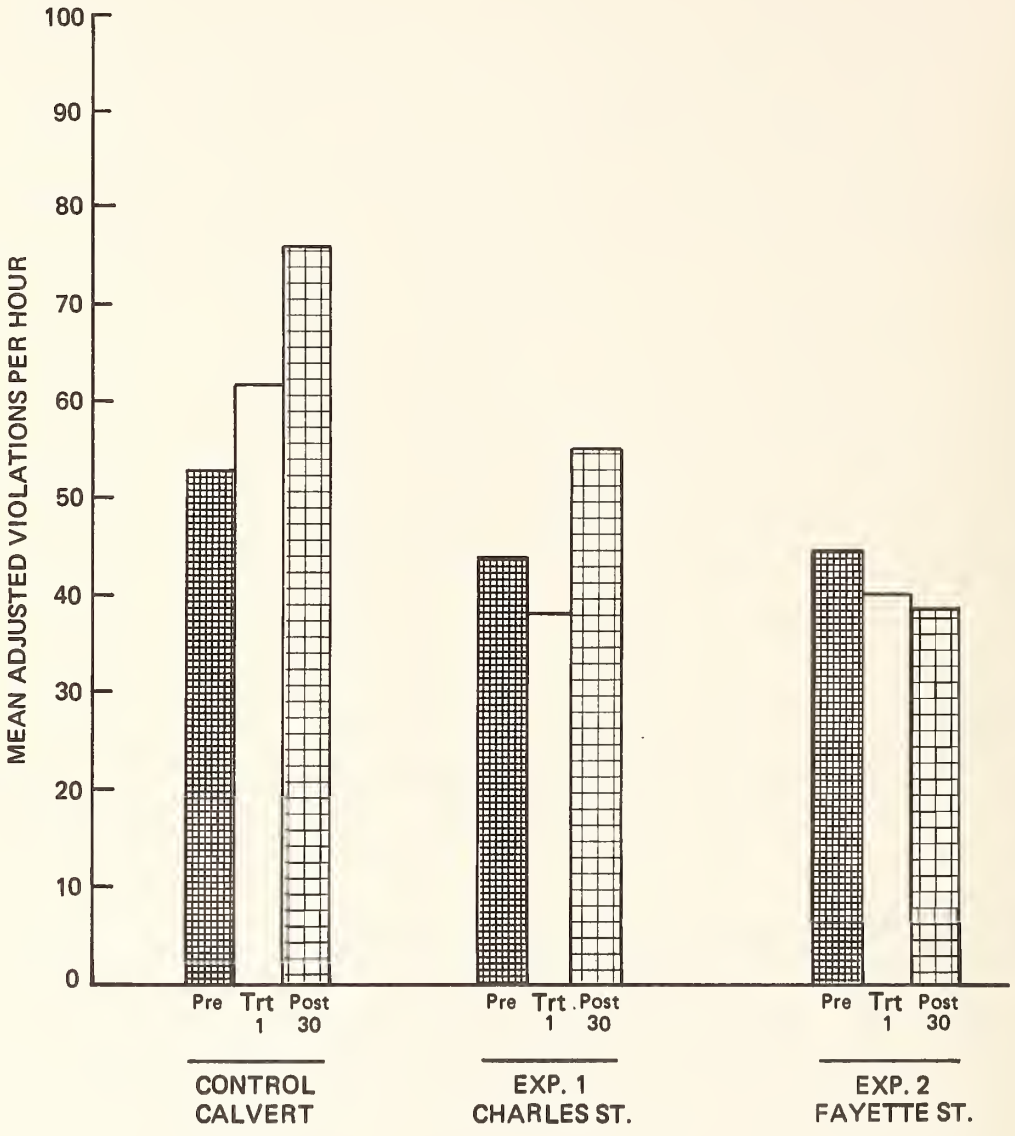


Figure 32. Adjusted mean violations over data collection periods for experimental and control sites.

and 2 by treatment and Post 30 interactions do not significantly add to the prediction of violations. This suggests that the two experimental treatments were not significantly different overall from the control site.

However, examining the detailed contribution of each factor and interaction (Table 12) reveals that the Post 30 data collection period is significant beyone the .001 level, and the Experiment 2 by Post 30 interaction is significant at the .01 level. This means that the Experiment 2 treatment (repeated use of a sign with all SUL information on it) was effective in reducing violations by about 14%. Figure 32 confirms this conclusion. Treatment 1 initially had an impact, but it did not last. A transition effect such as this could be due to novelty, especially for a unique treatment such as split presentation arterial signing.

Temporary Intrusion Violations

There was no parking allowed on Fayette Street, so the available comparison was between the control street (Calvert Street) and Experiment 1 split sign presentation street (Charles Street). Figure 33 presents the mean adjusted violations in the "before," "Treatment 1," and "after 30-day acclimation" time periods for both streets.

A step-wise regression analysis found the covariate right turn volume, adjacent lane volume, and bus volume all contributed significantly in accounting for temporary intrusions. These, plus the experimental variables (data collection periods and treatments) and the interactions, resulted in a multiple correlation with temporary intrusions of R = .91. Table 13 gives the regression equation significance test results.

Table 12

Significance Tests for the Regression Equation Predicting Violations--Baltimore

Multiple R = 0.52482

R Square = 0.27543

Variables in the Equation

Variable	B	F
Bus Volume	0.4773 (+00)	14.15*
Volume	0.3601 (-01)	5.35
After	0.9185 (+01)	2.37
Post 30	0.2264 (+02)	14.29**
Experiment 1	-0.9288 (+02)	2.26
Experiment 2	-0.8910 (+01)	1.53
Experiment 1 x After	-0.1547 (+02)	3.53
Experiment 1 x Post 30	-0.1185 (+02)	1.97
Experiment 2 x After	-0.1311 (+02)	1.55
Experiment 2 x Post 30	-0.2887 (+02)	8.28*
(Constant)	0.1776	

* = .01

** = .001

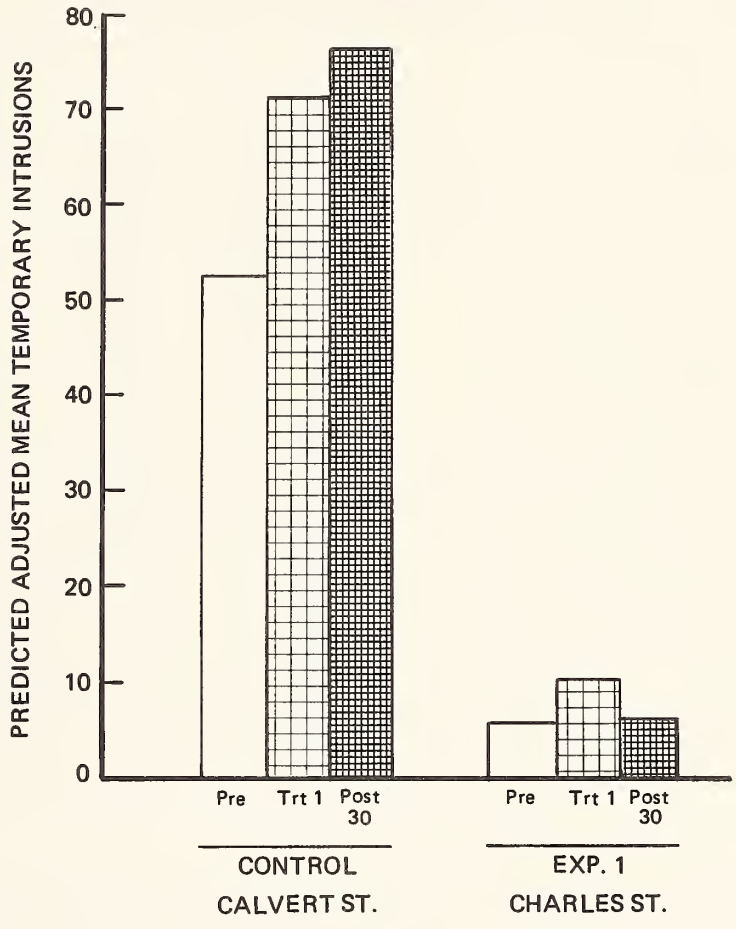


Figure 33. Adjusted mean temporary intrusions on the SULs – Baltimore.

Table 13

Final Regression Solution for the
Temporary Intrusion Measure--Baltimore

Multiple R = 0.924

R Square = 0.836

Variables in the Equation

Variable	B	F
Right Turns	-0.7013 (-01)	0.71
Bus Volume	0.1707 (+00)	1.74
Volume	0.5494 (-01)	16.16*
After	0.1886 (+02)	21.59*
Post 30	0.2326 (+02)	32.84*
Experiment 1	-0.4749 (+02)	115.50*
Experiment 1 x After	-0.1901 (+02)	11.46*
Experiment 1 x Post 30	-0.2356 (+02)	16.76*
(Constant)	0.2568 (+02)	

* = p > .001

The magnitude of the temporary intrusions on Charles Street was small (5 to 10 per hour over a four-block area). Although installation of the signing treatment resulted in a doubling of the intrusions, this is more likely explained by the decrease in violations. Fewer violations meant more available space to weave in and out of the SUL, particularly to scoot around congestion at intersections. After 30 days, violations increased and the temporary intrusions decreased again.

In short, the signing treatment apparently had a relatively minor direct effect on temporary intrusions. Instead, the signing affected violations which, in turn, impacted temporary intrusions.

Bus Time

Running time through the experimental portion of the SULs was collected on a sampling basis for buses. The hypothesis tested was that upgraded signing would reduce running time by eliminating violators. An analysis of variance of the three streets and before/after/Post 30 data collection periods indicates a significant difference between Fayette (experimental) and the other streets, but no differences between time periods. Thus the hypothesis was not supported.

There is reason to consider the short experimental sections as an inadequate test of the hypothesis. First, there would have to be large numbers of violators causing considerable bus delay for the signs/markings to have anything to change. This was not the case, particularly with the sequenced signals on Charles and Calvert Streets, which minimized the effect of violators. Therefore, the bus time data add no insight into the effectiveness of the information system. This is not to say that bus times might not be a useful MOE of signing under different traffic and SUL length conditions.

Weaving Prior to the SUL

The control street did not have an area in advance of the SUL that was suitable for data collection, so only before-after studies could be performed on the two experimental streets.

All traffic moving through the one-block data collection area at each street was categorized as:

Type 1--already in left lane, no shift or weave required.

Type 2--late shift; weave from right to left lane in block prior to SUL.

Type 3--stay in right lane and enter SUL as violator.

Figure 34 displays the proportion of vehicles in each category for the different data collection periods. Each period consisted of two rush hours per day for four days.

The advance signing had a negative effect on weaving at both sites. The decrease in Type 1 vehicles on Fayette Street was significant after treatments were installed ($z = 2.8$, $p < .01$), but not after 30 days acclimation. On Charles Street, the decrease was significant ($p < .01$) for both data collection periods. These changes were reflected in increased late lane shifts. Violations of the SUL did not change statistically.

Since there was no control site, it is difficult to know if these changes were strictly because of the signing or because of other traffic conditions prevalent in Baltimore. The comments from the drive-through debriefings which follow indicated that the advance signing was confusing--the information displayed was not self-explanatory. Drivers did not immediately know what either the diamond or the word "restricted" meant.

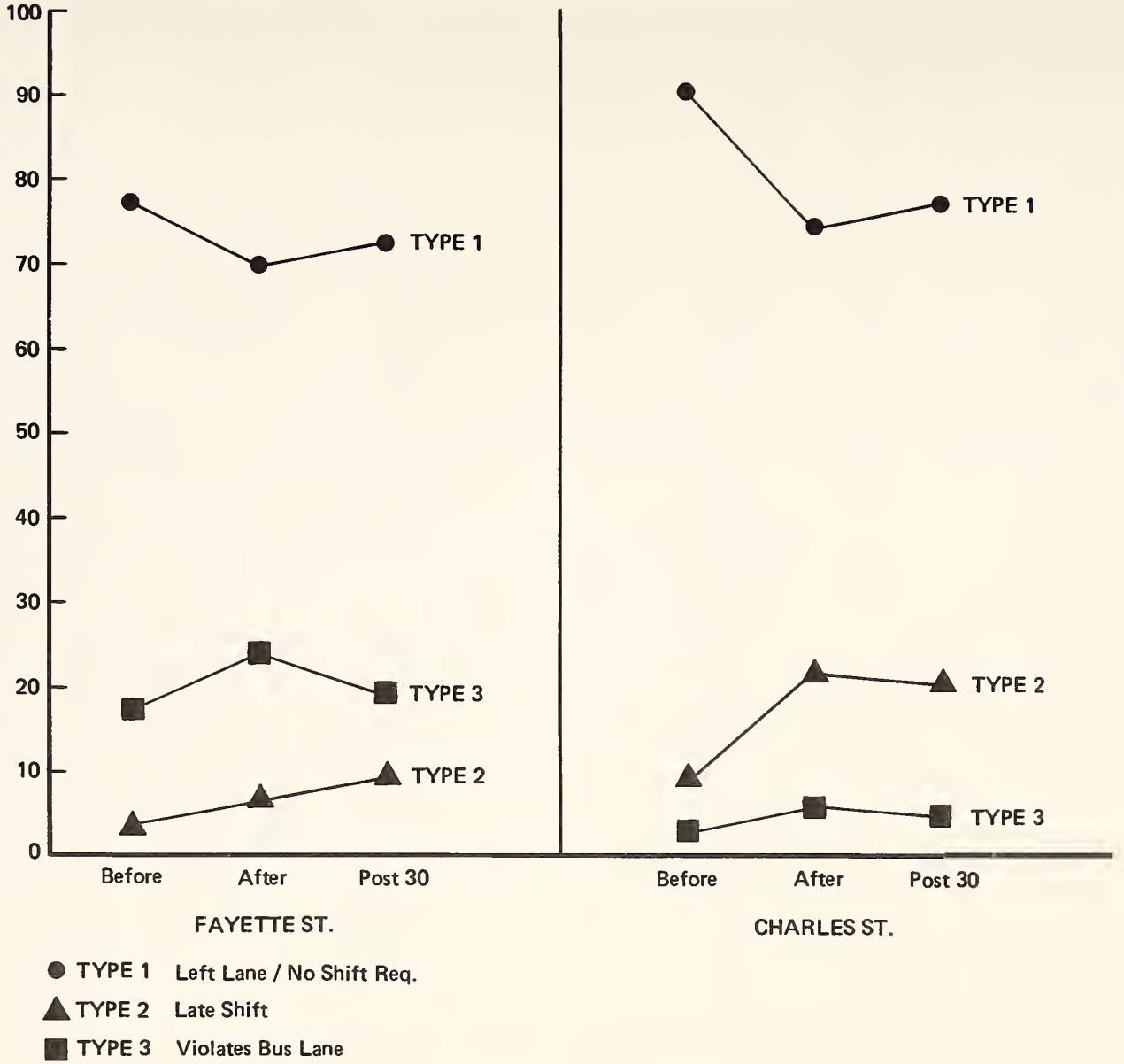


Figure 34. Proportions of traffic shifts before and after advance sign installation on the experimental streets – Baltimore.

Advance signing has a major role in providing SUL information; however, the signs used in this study apparently do not carry significant information to be understood--particularly in a setting where diamonds and/or SULs are first introduced. Based on this interpretation, advance signs should carry the following information: diamond symbol, which lane is restricted, and what the restriction is. Thus the advance sign becomes similar to the through signing, but with the words "ahead" or "ahead x blocks" added.

Driver Perceptions and Reactions

The stratified sampling plan for drive-throughs was achieved exactly as designed. Responses to the questions confirmed several of the findings from west coast (San Francisco) drivers. For example, 60% of the drivers remembered noticing information about the right lane (SUL). One reason that signing treatments are not more effective is that a substantial proportion of the drivers simply are not aware that they exist. This same question tallied by other variables is equally revealing (see Table 14).

The unfamiliar drivers appeared to be aware of their "condition," and paid somewhat more attention to the information system. They were also more aware of the experimental SUL signs than the familiar drivers (50% vs. 38%).

Rush hour usually means decreased attention and scan time for signs. This was not evident in awareness of SUL information, where 50% of rush and non-rush hour drivers were aware of the SUL.

Even though they were test subjects with an experimenter in the car, four drivers (16.6%) were SUL violators. When asked to identify the signs they saw along the drive from photographs, the responses were:

	Unfamiliar		Familiar		Total	
	#	%	#	%	#	%
Old SUL sign on control street	8	33	10	42	18	37.5
Experimental advance sign--SUL	6	25	8	33	14	29.1
Experimental through sign--SUL	12	50	9	38	21	43.8
Overhead SUL sign (not in Baltimore)	2	5	4	17	6	12.5
Symbol SUL sign used elsewhere in Baltimore	1	4	0	0	1	2
Snow emergency route sign	8	33	13	54	21	43.8
No stopping sign	16	67	16	67	32	67
None	2	5	1	4	3	6

Table 14

Response to: "Did You Notice Any Information About the Use of the Right Lane on Streets You Just Traveled?"

Total

Yes: 60% No: 40%

By Route

A (Fayette)	B (Charles)
Yes: 34%	Yes: 66%

By Time

Rush	Non-Rush
Yes: 50%	Yes: 50%

By Familiarity

Familiar	Unfamiliar
Yes: 42%	Yes: 58%

Advance signing was not recalled by more than one-third of the drivers. Of all the SUL signs, the experimental "through" sign was best recalled, but still by less than one-half of the drivers. Even the numerous "no stopping" signs were only recalled by two-thirds of the drivers. The SUL signs along the two blocks of Fayette Street were not as well recalled as the Charles Street signs. However, violations were reduced on Fayette, not Charles Street. Memory processes are influenced by dimensions such as novelty or uniqueness and exposure. There were four blocks of Charles Street signs, but only two of Fayette Street signs. Certainly the split presentation signs were unlike any the subject drivers had seen before. The drivers who noticed them tended to remember them. These data again illustrate that seeing a sign is a necessary prelude to using the information displayed, but does not guarantee that the information will be remembered and/or followed.

Subjects were asked to indicate what meaning was conveyed to them by various signs seen during their drive. Distractor signs not on the Baltimore streets were included among the alternatives. Responses were categorized as: Can use lane, Cannot use lane, Bus only lane, Shoulder lane, Breakdown lane, or No meaning. The experimental and existing SUL signs were equally well interpreted, with 85% of the drivers giving a correct response, 6% an incorrect response, and 9% a "don't know" response. Drivers were also asked how certain they were of their responses. Eighty-three percent indicated a 4 or 5, certain or very certain.

The driver perception data supported the behavioral data for the advance sign. Approximately 46% of the drivers gave a correct response, but another 46% did not know what the sign meant, and the remaining 8% gave an incorrect response. The certainty of driver response varied widely from 29.2% at the 1 (very uncertain) end, to 25% at the 5 (very certain) end.

An overall preference question, which sign best conveys the information needed about the SUL, was asked of each subject driver. The existing Baltimore signs were chosen by 57% of the drivers, while 43% chose the experimental signs. This difference was not statistically significant ($z = .97^2$).

Subject drivers were asked for suggestions to improve signing and markings. The most common ideas were:

- Make signs larger--28%
- Explain diamond symbol more--26%
- For the split presentation route only: Put the information on one sign--16%
- Make sign lettering larger--13%.

Drivers were also shown pictures of four types of delineation and asked to recall if any were seen along their drive and what it meant to them. Seventy-five percent recalled seeing standard double yellow or white skip lines. Only 35% recalled the diamond marking. However, when asked which of the four markings best conveyed the SUL concept, 71% selected the diamond.

The diamond appears to be an effective symbol, but it must be made more visible. This is not surprising in dense traffic areas where the probability of a mid-lane symbol being covered rapidly increases with increasing vehicle (particularly bus) volumes. Since buffer zone designs including the diamond are not as likely to be covered, they appear to be one method of increasing diamond visibility.

Conclusions

The split presentation signing was not effective. Information all on one sign was effective in reducing violations compared to a control street. Temporary intrusions into the SUL were reduced initially, but the effect was gone after 30 days. The SUL advance sign tested had a negative impact on weaving and was confusing to one-half of the drivers tested. Drivers noticed the experimental signs more than the control signs, but only 60% of the drivers were aware of an SUL. SUL signing probably needs to be supplemented with special public relations. Mid-lane diamonds were noticed by only 38% of the drivers, but the symbol was selected as best in denoting the SUL by 71% of those tested.

Thus the results suggest that, in heavy traffic density, the larger sign and lettering with all of the information on one sign is most appropriate. Use of the diamond on the sign and mid-lane is indicated, but added visibility for the diamonds on the pavement is necessary. The buffer zone is one posible solution. The wording on signs should be the same as on the experimental signs since they were more effective in violation reduction than the control signs, even though they were equally clear in conveying information according to driver preference.

CHAPTER 6

FIELD STUDY #5: FIELD TEST OF CARPOOL DEFINITION SYMBOL SIGN (Seattle, WA)

Purpose

The carpool ramp study was designed to evaluate whether the use of symbolic signs to designate eligible ramp users would impact upon reducing violators (non-eligible users) of the ramp. There are two long ramps extending from Interstate 5 in Seattle, Washington, that divide into bus/carpool only sections to provide priority access into the city. A carpool here is defined as three or more persons in the car.

A previous laboratory study (see Volume II) revealed that certain symbols convey the designation of a carpool better than worded messages. Since it was observed in a pilot study that the Seattle ramps carried a fair number of violators as well as carpools, it was reasoned that installation of new symbol signs might effect some reduction in ramp violators.

Experimental Design

The paradigm of this study was before-after with one ramp serving as the experimental site for new sign installation and the other, the control site, with no signing changes. Data were collected during two one-week periods, before and after the new installation, on both ramps. Given weather conditions, three days of good data were obtained for each period.

Site Description and Information Treatment

The carpool ramps are extensions of I-5 in Seattle, exiting southbound into downtown Seattle. The experimental ramp ended at the corner of 9th Avenue and Pike Street from the underground section of the reversible lanes of I-5. Further downstream from this ramp was the control site, a ramp that extended onto 5th Avenue, accessed by Columbia and Cherry Streets. Figure 35 presents a diagram of the general layout of these ramps as they are embedded in the I-5 system, along with close-up sketches showing pertinent sign placements. Note that on the experimental ramp there are three signs designated. General southbound traffic on I-5 which does not meet the 3-person carpool requirement must access Terry Street at points further south, rather than 9th and Pike or the Columbia/Cherry Streets system.

The new sign installations to replace the three key signs on the 9th and Pike ramps are shown in Figure 36. The before and after designs used on the ramp are shown. The new designs were based on the most promising symbol that emerged from the laboratory study (see Volume II). Washington Department of Transportation officials fabricated and installed these for the research purpose and were cooperative throughout the research process. Figure 37 presents a number of photographs of the experimental and control ramp sites showing some of the signing used.

Methods and Measures

Manual counts of violators and carpools were taken during the before and after data collection periods. Unobstrusive observers were stationed by each ramp during the inbound rush hours from 7:30 to 9:00 a.m. In addition, overall volume and bus activity was recorded to note any seasonal changes that might have had an effect.

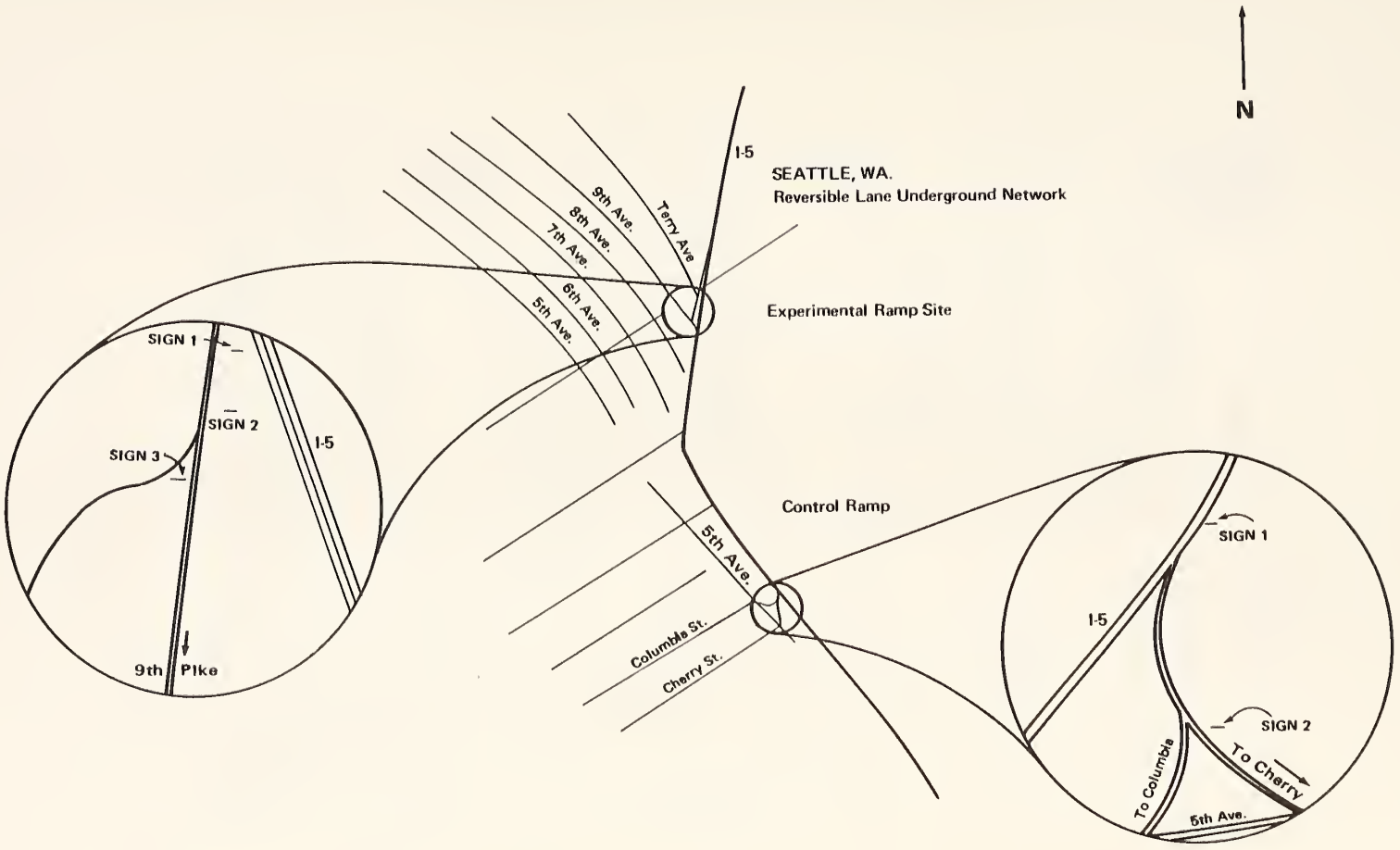


Figure 35. Experimental and control ramp sites for carpool symbol sign study—extending from I-5—Seattle (not to scale).

BEFORE (All reflectorized)

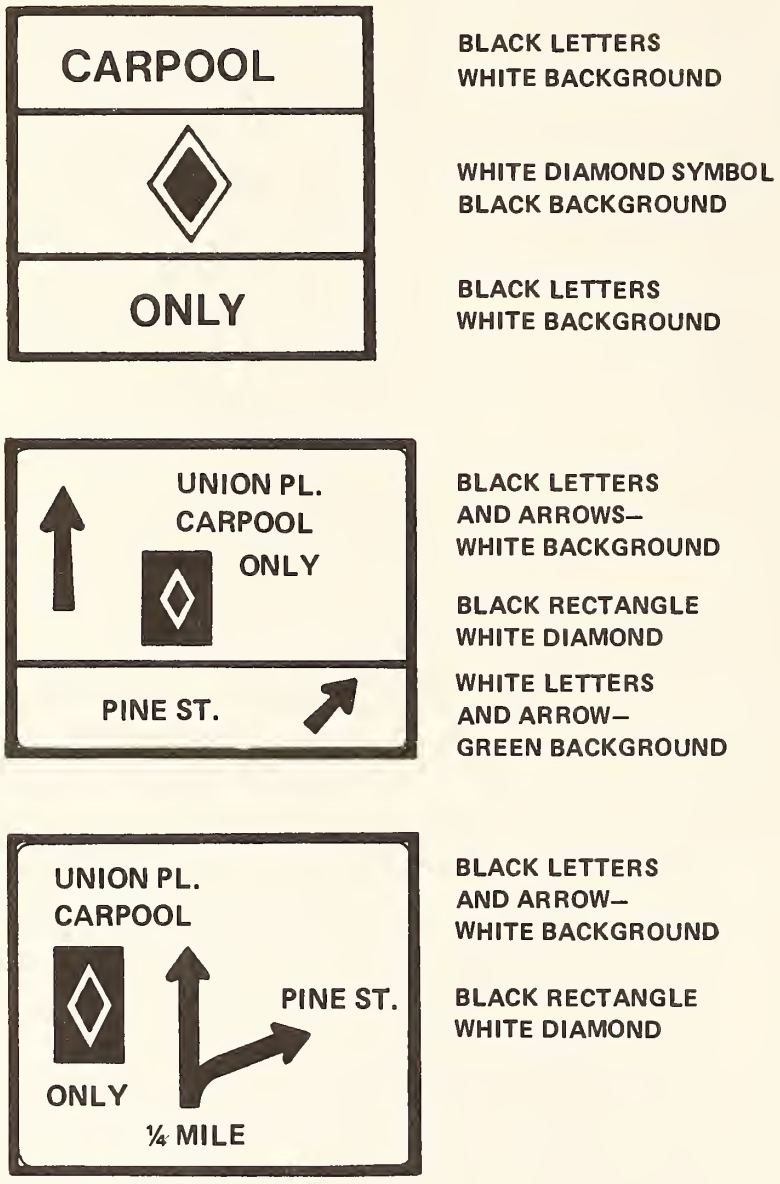


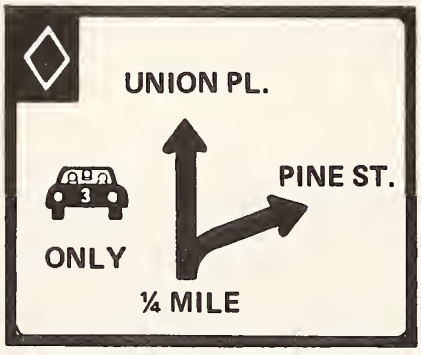
Figure 36. Carpool symbol signing–current and experimental.

AFTER (All reflectorized)

BLACK LETTERS
WHITE BACKGROUND

WHITE DIAMOND SYMBOL
BLACK BACKGROUND

BLACK LETTERS
WHITE BACKGROUND



BLACK LETTERS
AND ARROWS–
WHITE BACKGROUND

BLACK RECTANGLE
WHITE DIAMOND

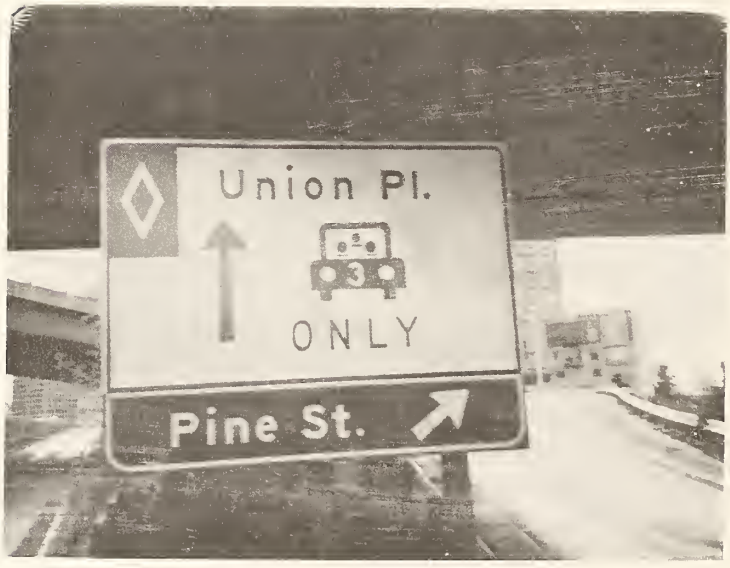
BLACK LETTERS
AND ARROW–
WHITE BACKGROUND

BLACK RECTANGLE
WHITE DIAMOND

WHITE LETTERS
AND ARROW–
GREEN BACKGROUND

Figure 36. (Continued)

A. 9th & Pike – before sign.



B. 9th & Pike – after sign (ramp on left).

Figure 37. Various on-site photos, 9th & Pike St. and Cherry St. off-ramps from I-5–Seattle.

C. 9th & Pike – after sign.

D. Cherry Street – approach to ramp.

Figure 37. (Continued)

E. Approach to Cherry Street sign reads "Carpool – 3 or More Persons".

F. Bottom of Cherry St. ramp at 5th Avenue.

Figure 37. (Continued)

A second type of data collected was red-light interviews of drivers detained at the bottom of the 9th and Pike experimental site ramp. The sample interviewed included both violators and carpools. The survey instrument used consisted of posing questions in flow chart fashion to determine whether the driver:

- Saw any signs pertinent to the carpool ramp
- Understood the meaning of the signs, i.e., who was eligible to use the ramp
- Had other comments about the signs, the carpool ramp, or other items.

Thus the direction of the questioning was dependent on whether they had seen the signs, then whether they were understood. The diagram of Figure 38 shows how the probing process occurred. Note that the first question is always the same, then the direction followed is contingent upon that response. Each driver interviewed was recorded as either a violator or a carpool.

Results and Discussion

Figure 39 is a graphical representation of the proportions of violators exiting the experimental and control site ramps, before and after the new signs were installed on the experimental ramp. Three days of data were taken for each period. In actuality these are averages of data taken over a week, accounting for poor weather conditions.

Figure 39 may be interpreted as follows. For each data day, out of the total vehicles using the ramp, a certain proportion were violators (less than three persons in the car). Carpools would be 1.00 minus this proportion. During the before and after periods, the violation rate remained virtually the same for both

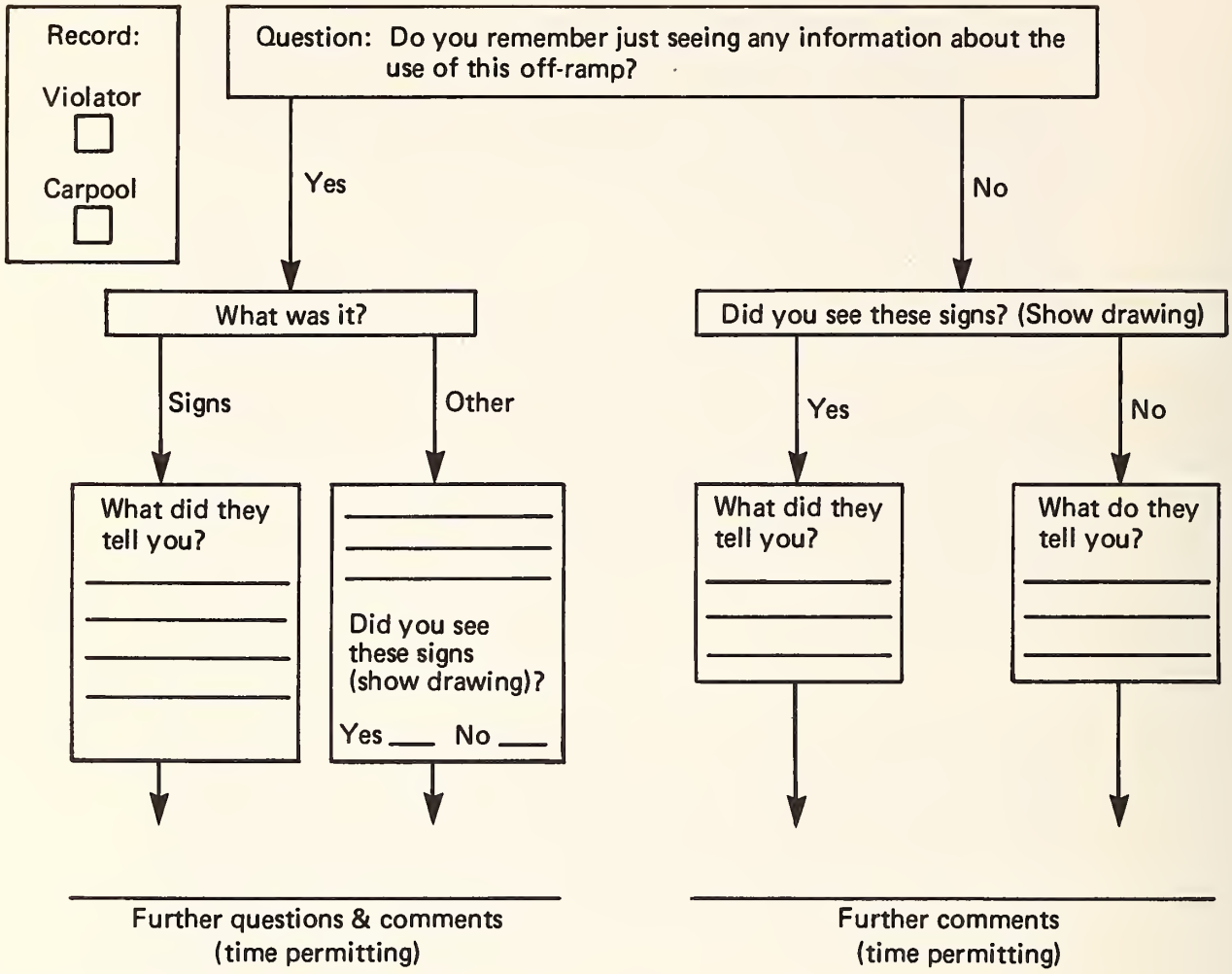


Figure 38. Probing survey instrument used for red light interviews on carpool ramp.

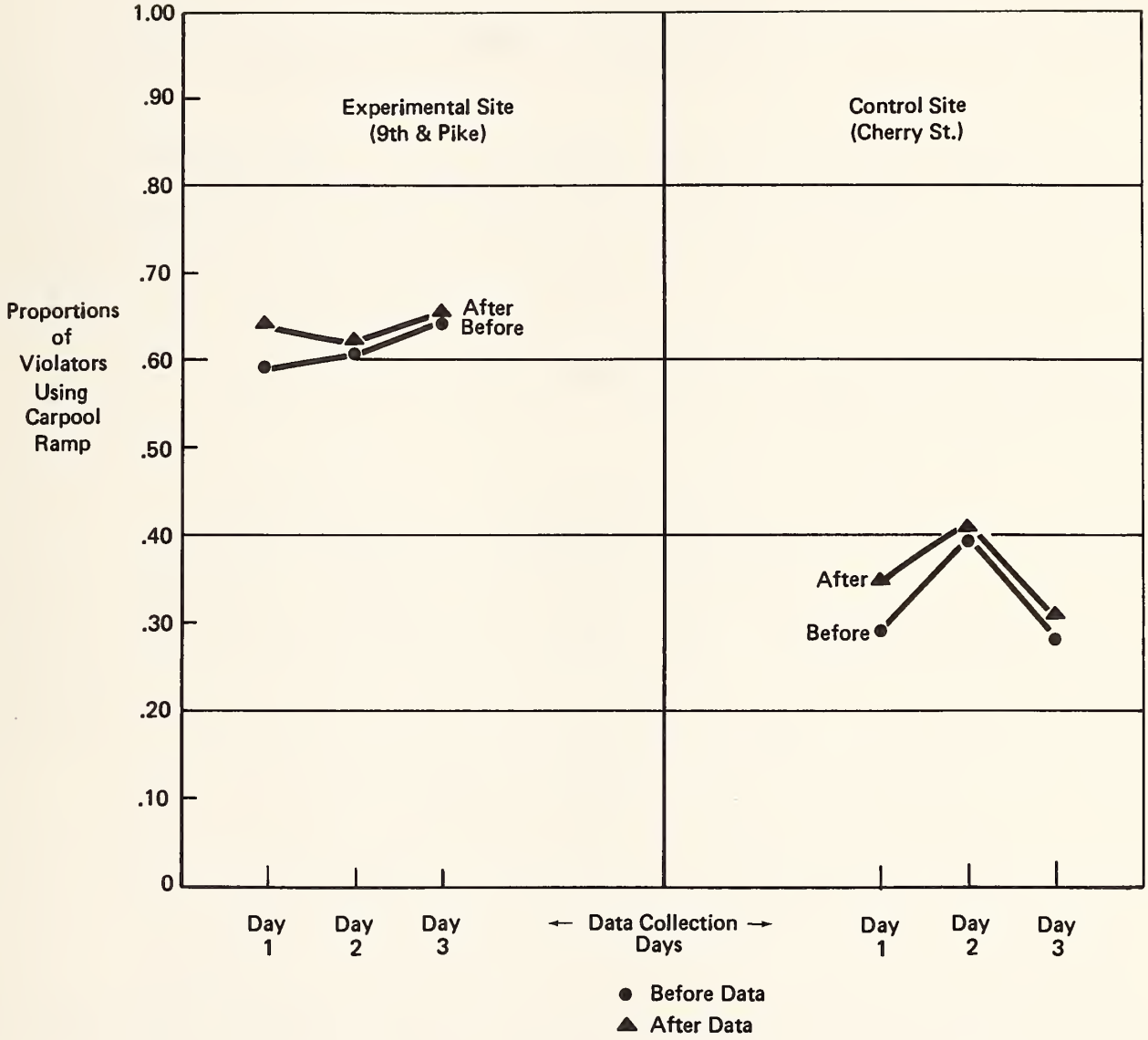


Figure 39. Proportions of violators (non-carpools) exiting priority carpool ramps on two sites before and after new symbol sign installation –Seattle.

the control and experimental sites. This was to be expected for the control site, and shows that seasonal characteristics had no effect on violations. Overall volume remained the same, and buses exiting the Cherry Street ramp remained at a consistent level. So installation of the new symbol signs at the 9th and Pike Streets ramp did not impact or reduce violations there.

The red light interviews conducted on the experimental ramp provide insight into why the signs seemingly had no effect. In all, 93 interviews were conducted before the new signs were installed, and 76 were conducted after the new signs. Below are the percentages of violators and carpools who indicated that they saw signing information about the ramp usage, in both the before and after conditions:

	Before New Signs				After New Signs			
	Violators		Carpools		Violators		Carpools	
	YES	NO	YES	NO	YES	NO	YES	NO
Saw the signs	37%	63%	74%	36%	50%	50%	80%	20%

The use of the symbol sign attracted more attention, and greater numbers of both violators and carpools reported seeing them. Even greater numbers recognized the signs when shown diagrams. Of the violators who did not report seeing signs at all, most said they were unfamiliar with the ramp, they were not paying attention, they had made a wrong turn, etc. Some of these sounded dubious, but this of course, could not be verified. Violators who admitted seeing the signs had a somewhat different attitude. Statements of the following types were frequently made:

- I saw the signs but I didn't know what they meant.
- I know this ramp is for carpools only but I didn't think they enforced it.

- I don't think it should be for carpools only, it's a better route to my destination and there's too much back-up the other way.

These types of statements indicate that the signs are as informative and prohibitive as they can be, but that actual behavior in response to them is at a lower priority than other factors. These factors include making time, taking advantage of limited enforcement, and general disregard for signs and signals unless pressed to do so. One driver actually insisted that the ramp violated constitutional rights.

Most of the legitimate users (carpools) reported seeing the new signs and preferred them over the previous signs in use. A few offered constructive suggestions to make the sign more clear -i.e., imbed the car into the arrow symbol, make the car larger, separate the Pine Street information from the Union Place information (refer to Figure 36). The fact that some carpool drivers did not notice either the old or new signs is attributed to one of the following factors:

- The vehicle met the 3 or more passenger criterion by chance rather than pre-planning.
- The carpool members were so acclimated to the daily use of the ramp that they were somewhat inattentive to the information.
- A small percentage of drivers were too preoccupied with the high speed deceleration from I-5 and other matters to notice the information.

Conclusions

The results of the installation of new symbol signs designating a priority (carpool only) facility showed that the new signing alone did not decrease violations. Proportions of violators using the exclusive ramp remained virtually the same.

On-site interviews of violators and legitimate users revealed that their behavior was not controlled so much by signs as by trip purpose: desire to use a good direct route and to slip by the authorities if possible. Since there was a reasonable number of violators in the ranks, a sort of undefined camaraderie was felt. The effects of the symbolic sign in detection, recognition, and user acceptance were excellent, and exceeded that of the non-symbolic type. Obviously, the optimization of the perceptual characteristics of the sign did not automatically trigger driver compliance to the law.

CHAPTER 7

FIELD STUDY #6: FIELD TEST OF SIGNS FOR STREETS CROSSING CONTRA-FLOW LANES

(Seattle, WA, and Harrisburg, PA)

Purpose

The objective of this study was to evaluate the looking behavior of drivers and pedestrians approaching a contra-flow facility from a side street. New signing treatments were designed to inform of the existence of buses coming from both directions along an otherwise one-way corridor.

In an analysis of user information needs along urban contra-flow lanes (see Volume II of this report), a problem identified was that traffic approaching contra-flows from side streets have no information about the buses coming from the direction opposite general one-way traffic. Signalized and freeway crossovers have safe, controlled passage across the contra-flow; unsignalized junctures require approaching traffic to look both ways first. The study addresses this need to look both ways.

Signs for drivers and pedestrians in this crossing situation were designed based on inputs from the laboratory studies and human factors analysis reported previously (see Volume II). It was reasoned that road users would look both ways for buses following the application of the new signing treatments to the cross street.

Experimental Design

A simple before-after experimental paradigm was used to evaluate changes in looking behavior among drivers and pedestrians approaching the contra-flow facility from a side street. Data were collected under each of the following conditions:

- Before sign application
- After sign application
- 30-days after sign acclimation/post-novelty period.

Two sites were selected for study based upon pilot observations. Many sites were located from information obtained through site inventory contacts (performed in previous tasks--see Volume II); however, only Harrisburg, Pennsylvania, and Seattle, Washington, had contra-flows with the unsignalized intersections needed for study. Thus the before-after paradigm was conducted in both an east coast and a west coast setting.

During the pilot observations, it was noted that looking behavior of traffic from the side street could be classified as "looks" or "non-looks," that is, looks were those who checked both ways (even though the street was signed as one-way only) and non-looks were those who did not. Additionally, these "two-way" looks seemed contingent on two factors. In the case of pedestrians, their proximity to the contra-flow curbs affected the looking; for drivers, the amount of queued traffic affected the two-way look. The closer the pedestrian to the curb of the contra-flow, the greater the tendency to look both ways. For drivers, when the side street was congested, the tendency to search both ways decreased.

A classification scheme for looks and non-looks, according to these driver and pedestrian factors, was developed. Table 15 shows a matrix summarizing the classification of the looking behavior as collected during the three treatment periods. Referring to the columns labeled "free-flow," this was defined as a driver approaching the stop sign at the contra-flow without encountering a queue. Non-free-flow meant a stop-and-go approach. Zones for pedestrian travel approaching the contra-flow are

Table 15

Cross Traffic Looking Behavior Recorded Urban Arterial Contra-flow Bus Lanes

Site Location / Road Factors / Approach Factors / Looks/Non/Looks (Both Ways) — Data Collection Period	East Coast (Harrisburg)												West Coast (Seattle)											
	Drivers				Pedestrians								Drivers				Pedestrians							
	Free-Flow		Non-Free-Flow		Zone 1		Zone 2		Zone 3				Free Flow		Non-Free-Flow		Zone 1		Zone 2		Zone 3			
	L	NL	L	NL	L	NL	L	NL	L	NL			L	NL	L	NL	L	NL	L	NL	L	NL		
Before Signs	# of looks (both ways)	# of looks (one way only)			etc.																			
After Signs																								
30-Day Acclimation to Signs																								

depicted in Figure 40. These zones proceed from approximately 20 feet away (Zone 1) to 10 feet (Zone 2) to curbside (Zone 3).

Site Description and Information Treatment

As stated previously, data collection took place in Harrisburg and Seattle. Local authorities in each city cooperated in allowing on-site observations and in installing the new signing treatments for the after data collection periods.

Figure 41 is a diagram of the contra-flow and cross street setting in Harrisburg. The contra-flow runs southeast on Market Street, while general traffic proceeds one-way northeast. Commonwealth Avenue and Market Street form the intersection under study. Existing signs are shown on the approach to the contra-flow from Commonwealth Avenue: conventional stop sign and one-way sign. Note that there is no notice to pedestrians.

Laboratory investigations and human factors analysis from preceding tasks (see Volume II) produced new signs to inform drivers and pedestrians of the bus traffic along the contra-flow. Figure 42 shows the designs used for each. The pedestrian sign was a standard 2'x 2' black on yellow advisory diamond plate, placed near the stop sign shown in Figure 41. Drivers viewed the "one-way except buses" placed on the left corners approaching from Commonwealth Avenue, near the observer's post, and replacing the existing one-way sign on the far side of Market Street. Figure 43 presents various site photographs taken at the intersection after new sign installation.

The Seattle contra-flow site was located at the intersection of Fifth Avenue and Jefferson Streets in downtown Seattle. Figure 44 shows a diagram of the site layout and characteristics.

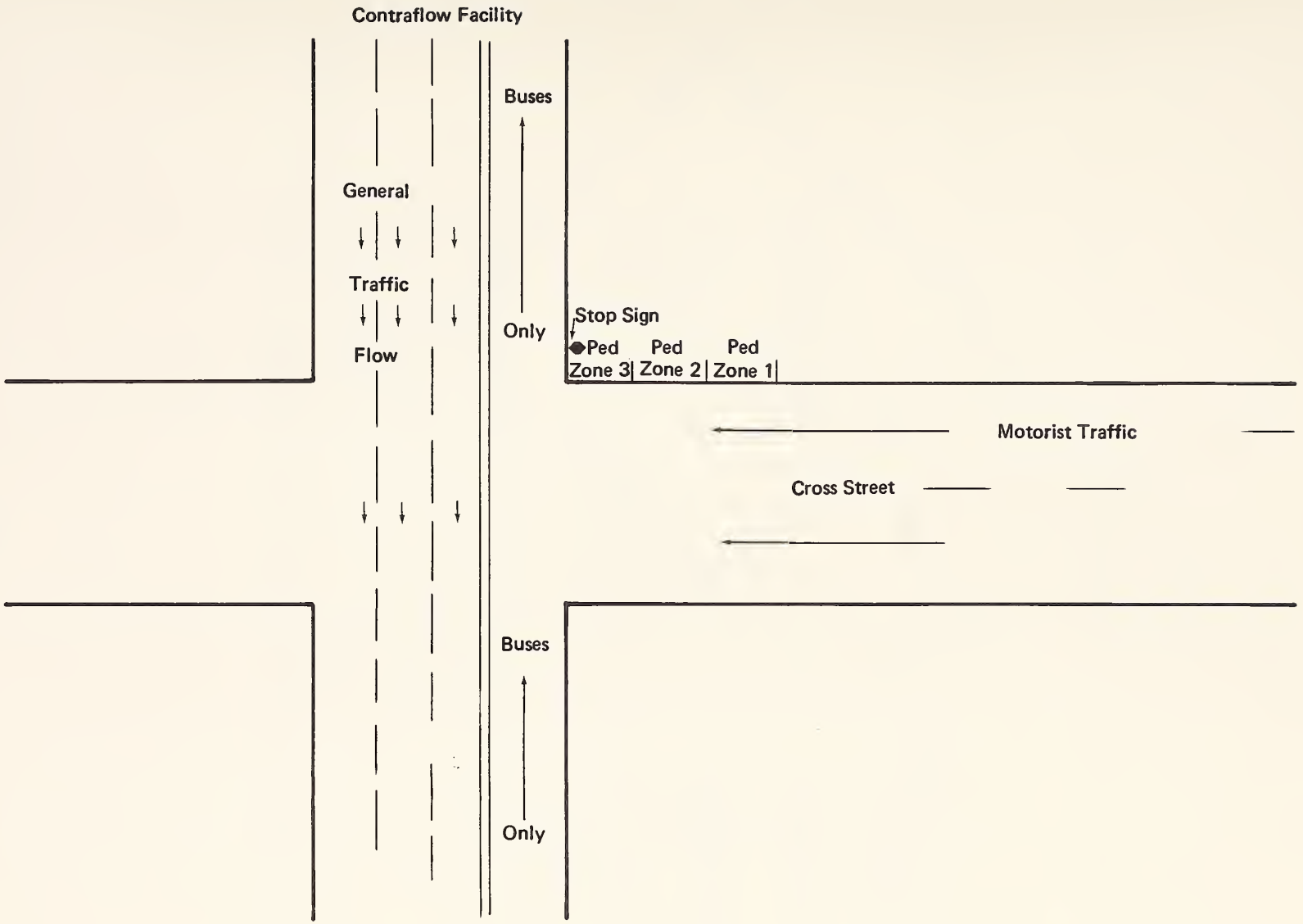


Figure 40. Pedestrain behavior zones of looking behavior defined for cross street traffic approaching contra-flow facility.

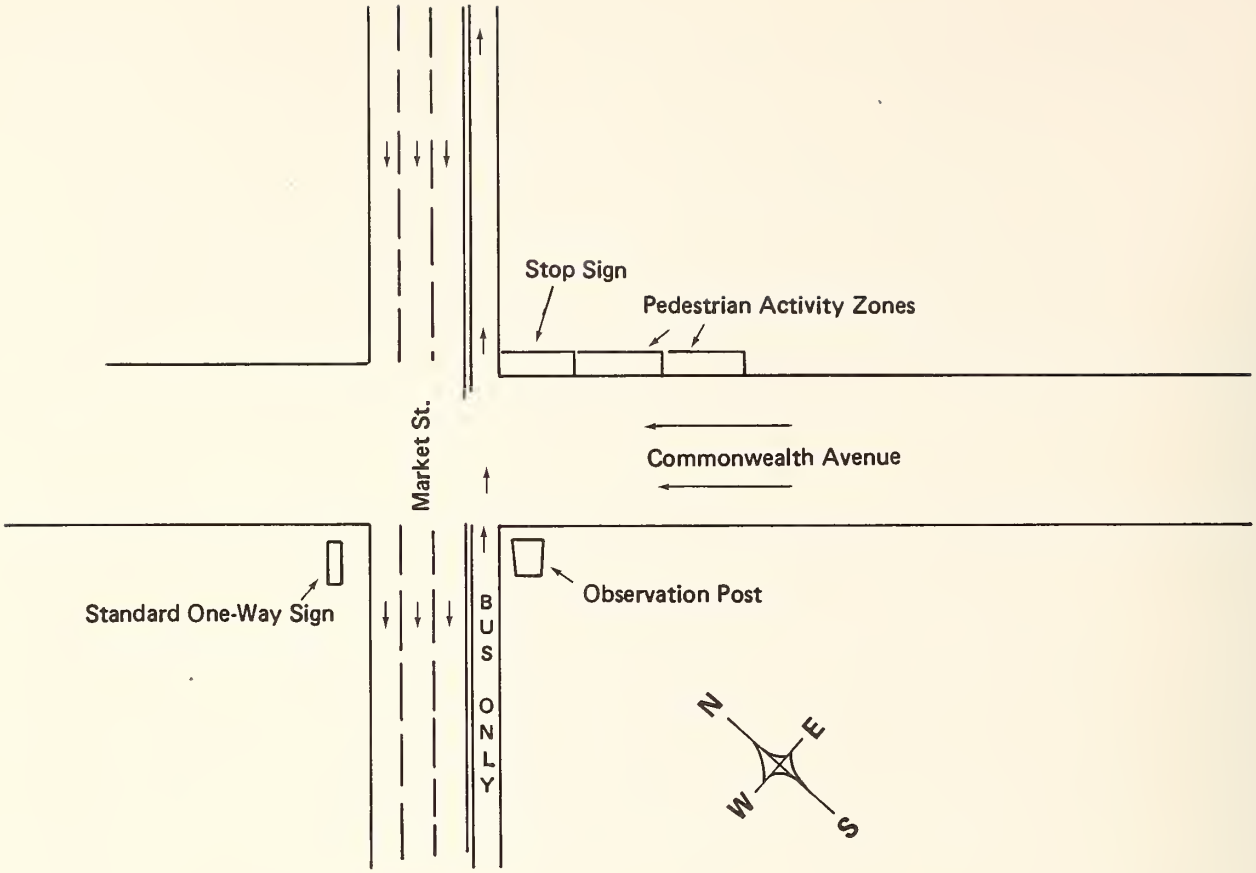


Figure 41. Market Street contra-flow bus lane at Commonwealth Ave. intersection – Harrisburg (not to scale).

Yellow and Black Sign
for Pedestrians

White and Black Sign
for Drivers

Figure 42. Design of contra-flow side street signs (not to scale).

A. Pedestrian approach to contra-flow facility
(Market St. on left).

B. Pedestrian approach to contra-flow
(Market St. in background).

Figure 43. Market St. and Commonwealth Ave. intersection with new sign installations – Harrisburg.

C. Pedestrian information sign —
curbside at contra-flow (Market St.).

D. Driver information signs — left curbside of
contra-flow and for side of Market St.

Figure 43. (Continued)

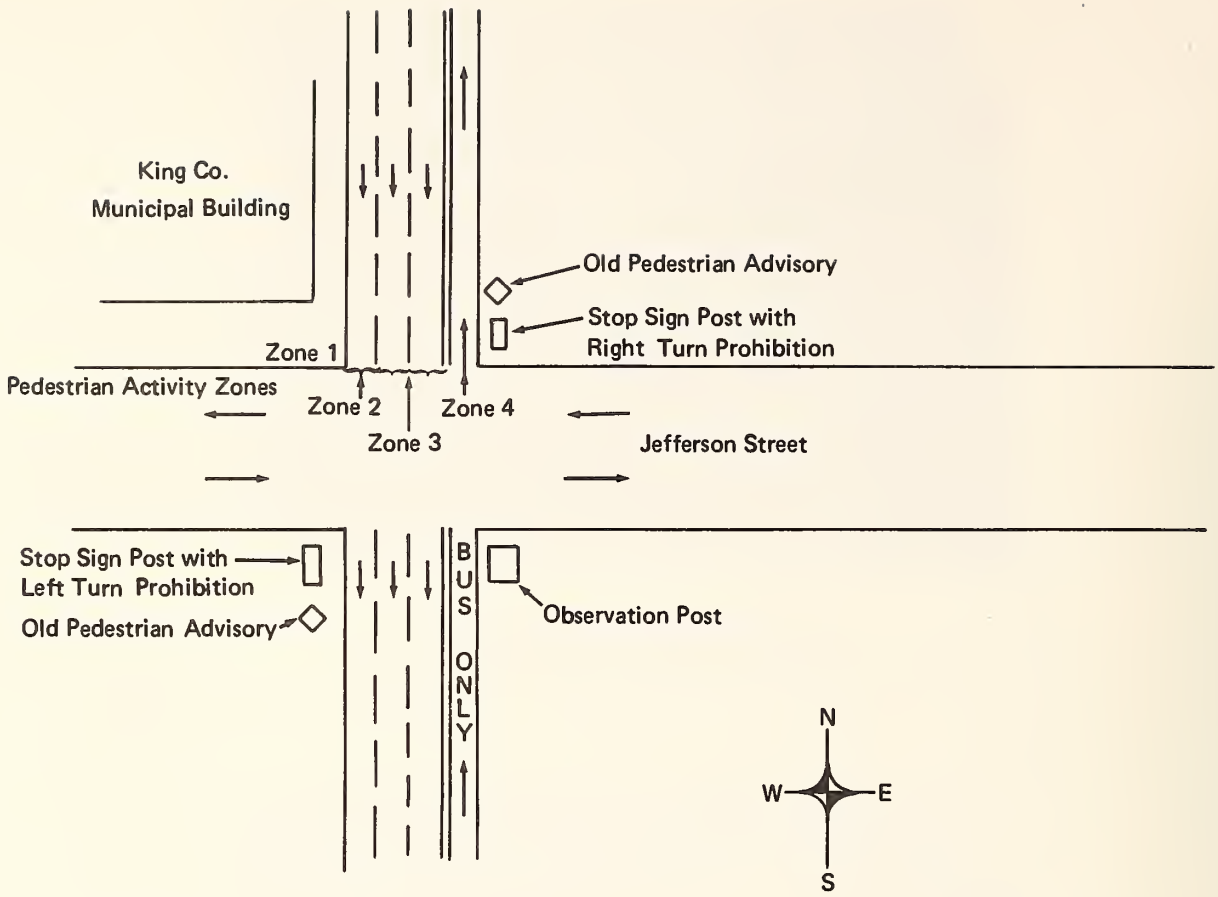


Figure 44. Fifth Avenue contra-flow bus lane facility at Jefferson Street juncture –Seattle (not to scale).

As can be seen, the contra-flow runs north along Fifth Avenue, general traffic proceeds southbound, and the unsignalized cross-over is Jefferson Street.

Several elements differentiate the Seattle site from the Harrisburg site. First, there were some existing signs advising cross traffic about the existence of the contra-flow prior to installation of the experimental signs. Figure 45 is a photograph of the westbound approach on Jefferson Street showing the placement of these former signs: On the left, for drivers, the "no left turn" prohibition, and, to the right, the pedestrian advisory, "buses operate northbound." So installation of the new signs (pictured in Figure 42) represented a slight upgrading of user information and offered consistency with the Harrisburg site. Second, pilot observations at this site revealed that pedestrian traffic during the p.m. rush hour was inordinately heavy from the westbound approach due to city workers vacating the King County Municipal Building (on the northwest corner). Therefore, driver looking behavior was evaluated moving westbound approaching the contra-flow, while pedestrian activity zones were defined curbside to contra-flow moving eastbound approaching the contra-flow. This is noted in Figure 44, which shows the pedestrian zones. The observation post on the southeast corner was well suited to view both driver and pedestrian activity.

Since the Seattle site considered both east- and westbound looking behavior, the new signs were installed on all four corners to give the needed exposure. Figure 46 presents a photograph of the westbound approach along Jefferson Street, showing the new sign installations for drivers and pedestrians.

Figure 45. User information along Jefferson St. approaching contra-flow before new sign installation—Seattle.

Figure 46. New sign installation westbound Jefferson Street approaching Fifth Avenue contra-flow lane—Seattle.

Methods and Measures

Collection of looking and non-looking behavior of cross traffic approaching the contra-flows was accomplished by time-lapse photography and manually coded counts taken during the data collection periods. Trained observers counted driver looks and non-looks for traffic under free-flow and congested conditions. Unobtrusively stationed Minolta XL-400 super-8 movie cameras filmed pedestrians throughout the data periods at one frame per second (see Figure 47). These films were later viewed and counts were made of pedestrian head movements within the activity zones previously outlined (see Figures 41 and 44). Counts and filming were suspended when a bus was detected in the bus lane since it was felt that this would cue looking behavior and confound tabulation.

Results and Discussion

The number of looks and non-looks by pedestrians and drivers was tallied for each data collection period at both sites. These will be discussed separately below.

The Harrisburg (Market Street) contra-flow crossing driver looking behavior is considered first. Proportions for each category were computed from the frequency counts of looks and non-looks. Table 16 presents the proportions as well as the combined total proportions for each data collection period.

Significant changes in looking behavior are evident from the data. Two chi-square analyses were performed on the raw frequencies used to compute these proportions. First, the chi-square of 252.78 for the combined total looks and non-looks is significant at $\alpha = .001$. This indicates that the sign installation did affect some increase in total two-way looks. Second, the chi-square

Figure 47. Experimental observers' posts – Harrisburg and Seattle.

Table 16

Proportions of Looks and Non-Looks by Drivers Crossing Contra-flow Bus Lane, Harrisburg

Congestion Level / Data Collection Period (Information Condition) / Behavior Type	Free-Flow		Non-Free-Flow		Combined Totals	
	Looks	Non-Looks	Looks	Non-Looks	Looks	Non-Looks
Before Sign Installation	.71	.29	.61	.39	.63	.37
After Sign Installation	.82	.18	.80	.20	.81	.19
30-Day Post Installation	.82	.18	.82	.18	.82	.18

X^2 Value = 356.77 df = 6 α = .001

X^2 Value = 252.78 df = 2 α = .001

value of 356.77 for behavior under free-flow and non-free-flow conditions is also highly significant at $\alpha = .001$. The congestion factor which previously diminished driver looks had been counteracted by the new signs.

Driver looking behavior for the Seattle site is presented in Table 17. The chi-square value of 61.62 for combined total looks and non-looks is significant at $\alpha = .001$. Further inspection of the looking behavior as affected by free-flowing and non-free-flowing conditions reveals that the increase in two-way looks was occuring when traffic was congested ($X^2 = 19.380$). Those drivers who could freely approach the contra-flow and make their cross-over apparently did not bother to institute the two-way looking behavior called for by the sign.

Figure 48 is a graphical representation of the driver looking behavior (two-way looks) in both Harrisburg and Seattle. In general the level of looks in Seattle is lower, and increases occur only when the traffic becomes congested and drivers search around due to the stoppage. Both sites show a somewhat dramatic increase after the new sign, then a tapering off in the post-30 period. This is a typical novelty effect syndrome wherein initial attention value of new information diminishes somewhat over time. The non-significant increase in free-flow drivers on the west coast is quite likely explained by the fact that Seattle had some signing regarding the two-way operation of Fifth Avenue prior to the new design installations (see Figure 45), so some previous acclimation may have occurred.

Pedestrian looking behavior in both cities will now be considered. Table 18 presents proportions of looks and non-looks by pedestrians in Harrisburg under the varying conditions. Totals within approach zones and curbside to the contra-flow are given, as well as in the overall total. Chi-square values were

Table 17

Proportions of Looks and Non-Looks by Drivers Crossing Contra-flow Bus Lane, Seattle

Data Collection Period (Information Condition) \ Behavior Type / Congestion Level	Free-Flow		Non-Free-Flow		Combined Totals	
	Looks	Non-Looks	Looks	Non-Looks	Looks	Non-Looks
Before Sign Installation	.64	.36	.55	.45	.59	.41
After Sign Installation	.65	.35	.75	.25	.71	.29
30-Day Post Installation	.68	.32	.71	.29	.70	.30

X^2 Value = 19.380

df = 6

α = .005

X^2 Value = 61.62

df = 2

α = .001

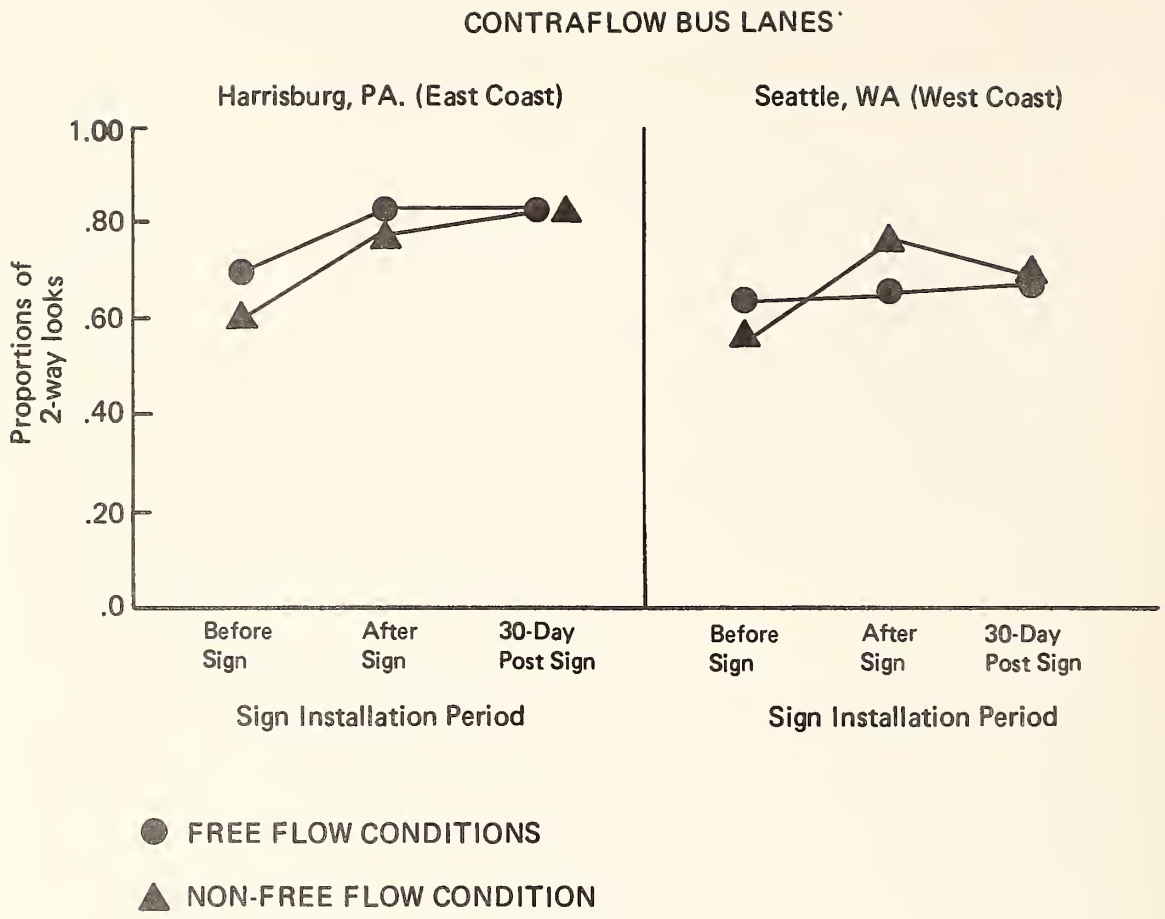


Figure 48. Proportions of driver two-way looks under free-flow and non-free-flow conditions crossing contra-flow bus lane in two cities.

Table 18

Pedestrian Looking Behavior Approaching
Contra-flow Bus Lane, Harrisburg

Data Collection Periods (Information Conditions) / Behavior Zones & Behaviors	Zone 1 Approach		Zone 2 Center		Zone 3 Curbside		Combined Totals	
	Looks	Non-Looks	Looks	Non-Looks	Looks	Non-Looks	Looks	Non-Looks
Before Sign Installation	.06	.94	.35	.65	.19	.81	.20	.80
After Sign Installation	.27	.73	.53	.47	.55	.45	.46	.54
30-day Post Sign Installation	.33	.66	.47	.53	.44	.56	.42	.58

$X^2 = 340.083$
df = 10
$\alpha = .001$

$X^2 = 262.078$
df = 2
$\alpha = .001$

computed for the zone frequencies and also for the combined frequencies of looks and non-looks. Both the zone chi-square value of 340.83 and the combined chi-square value of 262.078 were significant at $\alpha = .001$ (10 df and 2 df). After the 30-day acclimation period, some decline or leveling occurred in the number of looks. This again follows from the expected diminution of initial attention-getting value.

Pedestrian looking behavior approaching the Seattle contra-flow bus lane is given in Table 19. Four zones of activity are recorded as well as the combined totals of looks and non-looks. Chi-square values of 253.832 and 47.546 were computed for the zone looking activity and the combined looking activity. Both of these are significant at $\alpha = .001$. However, the data here are not clear, easily interpretable increases. Only in zone 4, foot crossover of the bus lane itself, does the proportion of looks increase as expected after sign installation. The combined figures reflect the confusing nature of the other data recorded. Overall looking behavior increases only after the 30-day period. This is markedly divergent from the previous pedestrian and driver findings. Instead of the drop-off or leveling effect, some increase is shown. A possible explanation may relate to the previously mentioned driver congestion factor in Seattle. As time was given to notice the new signs, more two-way looking behavior occurred. It will be recalled that Seattle had previous sign installations with certain similarities to the new designs.

Figure 49 presents a graphical comparison of the east coast and west coast pedestrian activity. In general, the installation of the new signs affects increased two-way looking activity in Harrisburg, which then levels off. In Seattle increases are noted after new sign installations, but post-30 day increases occur in variable fashion. Looking behavior at the Seattle site

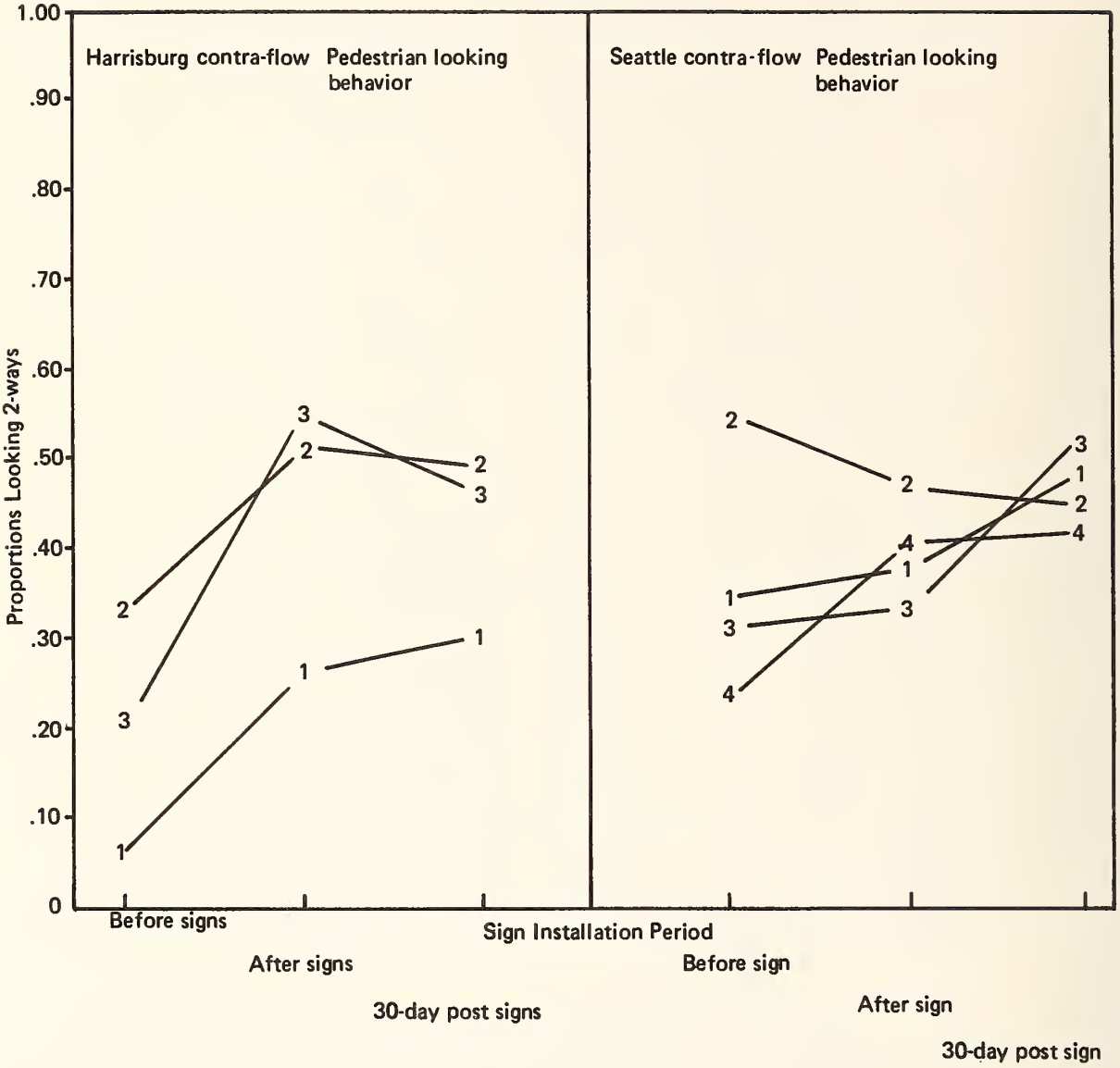
Table 19

Pedestrian Looking Behavior Approaching
Contra-flow Bus Lane, Seattle

Data Collection Periods (Information Conditions) / Behavior Zones & Behaviors	Zone 1 Approach		Zone 2 Approach		Zone 3 Approach		Zone 4 Approach		Combined Totals	
	Looks	Non-Looks	Looks	Non-Looks	Looks	Non-Looks	Looks	Non-Looks	Looks	Non-Looks
Before Sign Installation	.36	.64	.57	.43	.33	.67	.25	.75	.38	.62
After Sign Installation	.39	.61	.49	.51	.34	.66	.44	.56	.41	.59
30-day Post Sign Installation	.50	.50	.49	.51	.52	.48	.45	.55	.49	.51

$X^2 = 253.832$
df = 14
$\alpha = .001$

$X^2 = 47.546$
df = 2
$\alpha = .001$



Harrisburg Zone Definitions
1 = Approach contra-flow
2 = Center approach
3 = Curbside contra-flow

Seattle Zone definitions
1 = Approach contra-flow
2 = Approach center
3 = Center
4 = Inside bus lane

Figure 49. Pedestrian looking behavior approach to contra-flow bus lanes from cross streets – Harrisburg and Seattle.

is more haphazard. In both cases an important increase occurred immediately following sign installation for pedestrians in the curbside zones (Zone 3 in Harrisburg, Zone 4 in Seattle).

Conclusions

The looking behavior for drivers and pedestrians crossing a contra-flow bus lane was significantly affected by new sign installations advising of the existence of the two-way traffic. The proportions of looks by both groups generally increased following the installations. In Harrisburg, both groups show an immediate increase in looks after the new signs with a tapering and leveling effect after 30 days. In Seattle, increased two-way looks were restricted to congested conditions for drivers and to pedestrians mainly as they were closest to intruding into the actual bus lane. The Seattle site was slightly more confounded since some informative signing was in existence prior to the new experimental signs.

Overall looking and searching behavior by drivers was substantially higher than that of pedestrians. Even with the increases demonstrated above, total percentage of pedestrians looking both ways was usually less than 50%, and at no time exceeded 60%. Percentage of drivers looking was almost always above 60%, with increases ranging to 82%. Obviously drivers are more attuned to visual display information to maintain cognizance of their safety and placement in the traffic stream. Pedestrians at both sites seemed more intent upon crossing the contra-flow facility to get quickly to the other side.

CHAPTER 8
FIELD STUDIES SUMMARY

The field studies are summarized by providing answers to the issues (from Table 3) which were the genesis of the operational experiments. Table 20 lists each issue, where it was tested, and the primary findings.

Table 20
Field Study Results By Issue Summary

Issue	Where Tested	Finding
Effect of buffer zone delineation in freeway.	Honolulu, H-1, concurrent flow bus/carpool lane.	Minimal but positive impact on violations, probably no more than 10% reduction.
		No effect on speed.
Effect of buffer zone in arterial settings.	Rochester--part-time concurrent flow bus lane.	Reduction in moving but not parking violations for low volume conditions.
	San Francisco--24-hour bus lane.	No clear reduction in violations.
		No change in temporary SUL intrusions.
Impact of solid versus dashed buffer zone designs.	Honolulu, H-1.	No difference detected.
Effect of upgrading overhead signs.	Rochester	Violations lowered under low volume conditions only, effect diminished after 30 days.
		Driver awareness of SUL increased.
		Drivers notice entire system, not signs or markings separately.

Table 20 (continued)

Field Study Results by Issue Summary

Issue	Where Tested	Finding
Effect of shoulder mounted versus overhead signs.	San Francisco	Violations reduced 25-40% by overhead signs.
		Drivers became more aware of SUL with overhead signs.
Effect of complete upgrading in information system (signs and markings).	Rochester--arterial	Reduction in violations up to 10% for low volume conditions but effect diminished after 30 days.
		Increase in driver awareness of SUL.
	San Francisco--arterial	Reduction in violations (25-40%) and temporary intrusions. Effect lasted 30 days only on one of the two streets.
		Increased driver awareness of SULs.
	Honolulu--freeway	Minimal change (10%) in violations due to buffer zone; violations appear to be primarily volume dependent.
Effect of adding lane diamonds, upgraded SUL signs.	Baltimore--arterial concurrent flow, part-time bus lanes.	Violations, but not temporary intrusions reduced but effect diminished over time.
		Single sign presentation was effective and understood by drivers; split presentation not effective but more noticed.
		Advanced signing had negative effect, insufficient information on these signs confused drivers.
		Lane and sign diamonds not well understood--driver educational needs evident.

Table 20 (continued)

Field Study Results by Issue Summary

Issue	Where Tested	Finding
Compare symbol and word only sign.	Seattle--freeway	The carpool symbol sign did not change violation behavior.
		Driver detection, recognition and understanding of the symbol sign exceeded that of the word only sign.
Effects of cross street signing for contra-flow lanes.	Harrisburg--arterial	Pedestrians and drivers increased two-way looking behavior.
		The effect was maintained at a slightly lower level after 30 days.
	Seattle--arterial	Driver two-way looking behavior increased initially; diminished only somewhat after 30 days.
		Pedestrian looking increased but only when close to the curb.
		Overall, drivers looked both ways more than pedestrians (60-80% versus 10-60%).

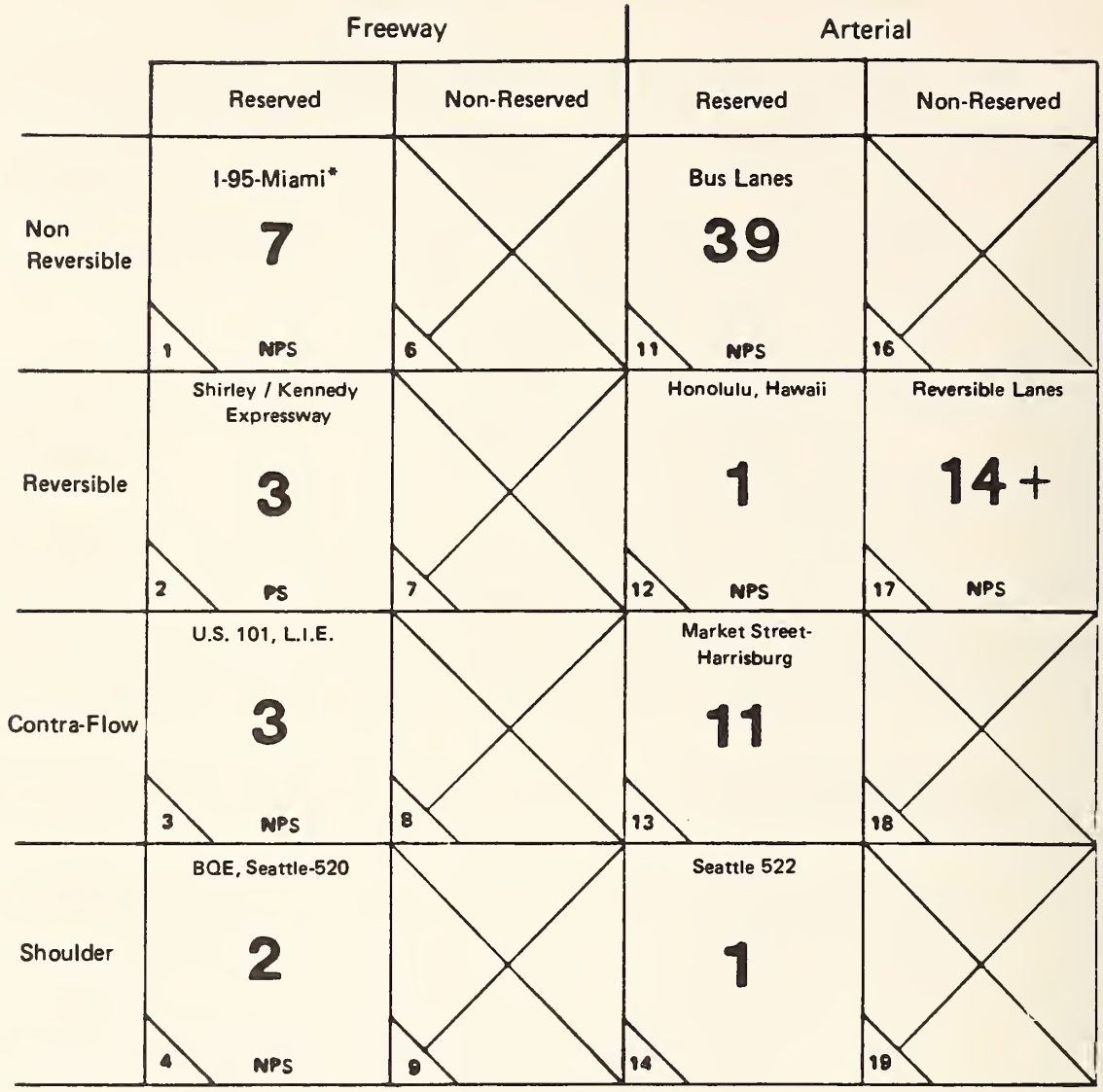
CHAPTER 9
INFORMATION SYSTEM CONFIGURATIONS

The ultimate objective of this project was to develop SUL information systems. That objective can now be reached by synthesizing the data from each of the previously described field studies. The result is a prototype information system for each of the nine cells in the SUL classification matrix (see Figure 1, repeated on the following page).

Each suggested system is incomplete in the sense that there is tremendous variability among SULs. Any information system suggested here would have to be tailored to the specific operational and geometric characteristics of the SUL. However, the information requirements and signing/marking mechanisms are enumerated here in sufficient detail to assure that standardization will result, even after adaption to a specific site.

Before discussing each cell, some general design features are noted.

- SUL signs are generally regulatory, so they must be black and white. For the larger freeway signs, the design standards for guide signs apply to SUL signs. To achieve the desired nighttime visibility (only where the SUL operates during dark hours), high intensity, reflectorized white letters on black background may be more effective than black on white. In arterial settings, black on white signs are sufficient, but reflectorization is necessary for night operations.
- Sign and message size on freeways is controlled by the guide signing design standards. On arterials, part of the improvement noted in the use of the experimental signs was probably due to larger size. Many existing



PS = Physically Separated.

NPS = Not Physically Separated.

* = At least one example or descriptor is listed for each cell.

Figure 1. Special usage lane categories requiring signing and delineation system development.

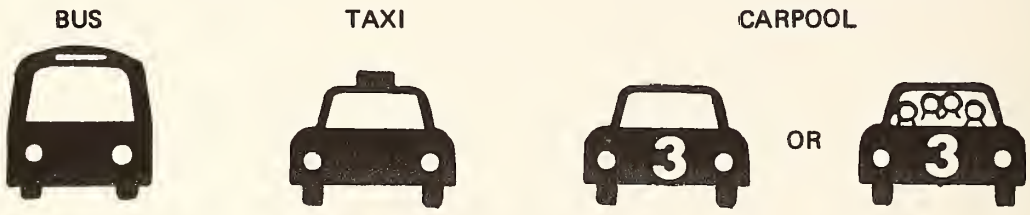
SUL signs start with large letters and provide time and day wording in small letters. By using larger signs, all the information is legible. The larger size also improves conspicuity. Thirty- by forty-inch signs with a minimum of three-inch letters, Series C,* were used in the field studies.

- Diamond symbols should be used for all reserved lanes. To be effective, the symbology must be carried through from sign to mid-lane and buffer zone markings. Educational or promotional materials should also feature the diamond symbol. Where possible, e.g., black on white signs but not white on black, a black sign heading and border is distinctive and becomes part of the symbology.

- Overhead sign placement is preferred to shoulder mounting. Whichever placement is used, care must be taken to clearly designate which lane the sign refers to, e.g., right lane with arrow pointing to lane.
- Buffer zone dimensions were given in Chapter 2. In general, 2" x 3" line widths, 3 or 4:1 length-to-width ratio for diamonds, and 12" to 18" buffer zone widths appear adequate. The data did not indicate a difference between a dashed and solid line buffer zone.

*Refer to U.S. DOT, Standard Alphabets for Highway Signs, FHWA, May 1972.

- Sign format can be either all word or word + symbol. The vehicle types allowed on the SUL should be noted. In other words, positive signing is suggested. For restricted lanes (the word "reserved" is suggested for HOV operations and "restricted" when a vehicle type is excluded), the negative wording, e.g., "No Trucks In Left Lane," is shorter, simpler, and clearer.
- Vehicle symbols should be front view. The following designs were empirically superior.*



Cell #1: Freeway/Reserved/Non-Reversible/No Physical Separation

This cell includes concurrent flow reserved full- or part-time lanes such as found on I-95 in Miami, the San Bernardino Expressway in Los Angeles, or the Banfield Expressway in Portland. Figure 50 presents the information requirements for each part of the SUL, the suggested requirements, and the source of support used for each sign/marking suggestion.

The buffer zone developed and tested in this project has been included as part of the suggested information system for the freeway and arterial (Cell #11) setting.

*Adapted from the PORT symbols described in: American Institute of Graphic Arts. The development of passenger/pedestrian-oriented symbols for use in transportation-related facilities. Office of Facilitation, U.S. Department of Transportation, Washington, D.C., November 1974.

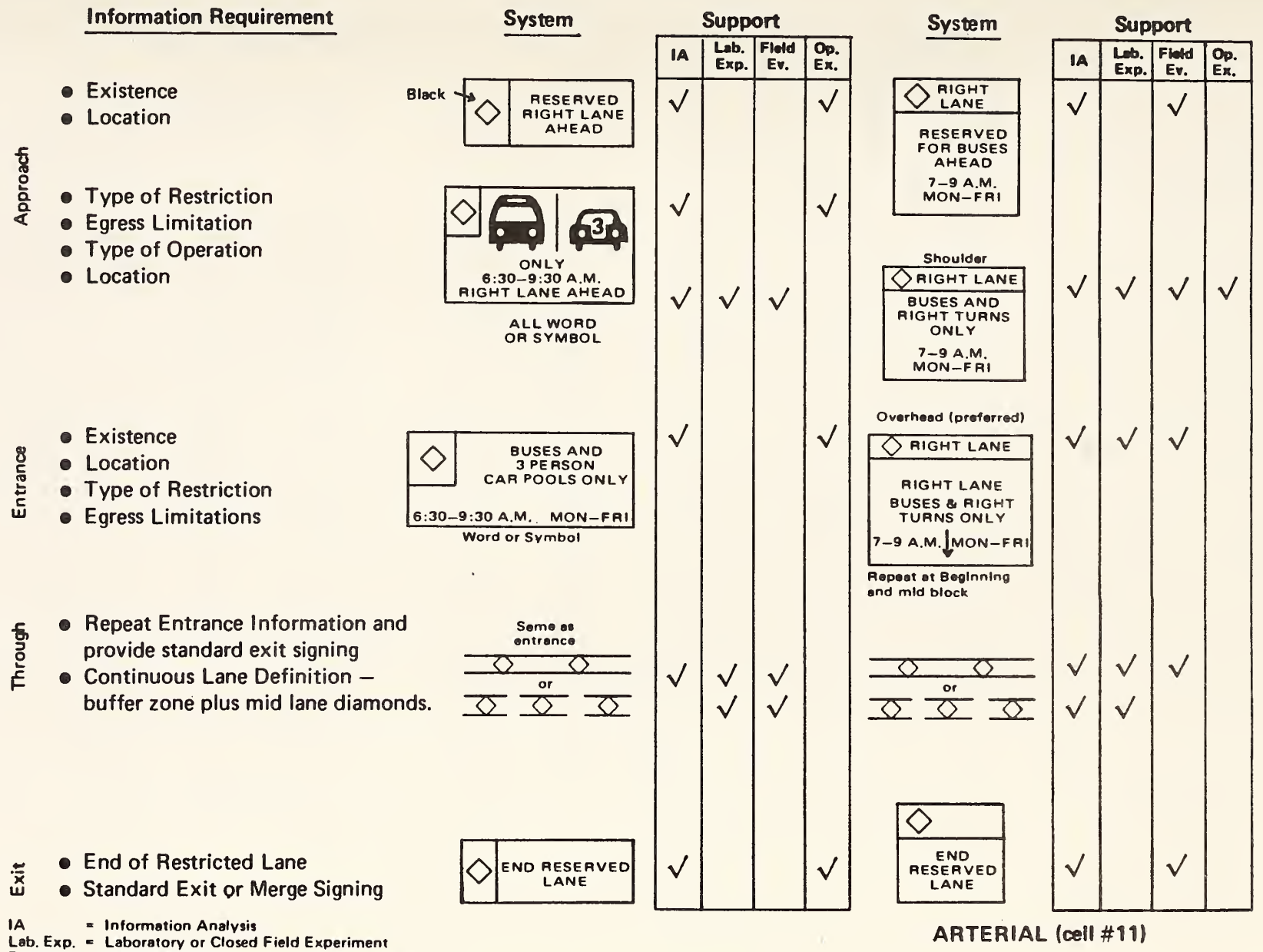


Figure 50. Freeway (Cell #1).

This delineation serves three functions. First, there is evidence that the buffer zone contributes to violation reduction, especially on freeways. Second, the buffer zone increases awareness of the SUL. Third, signing and the buffer zone comprise an information system that has a unique identity and, particularly on arterials, increases SUL awareness and reduces violations.

The double line diamond design is specifically suggested for concurrent flow operations because it was field tested and because it does not conflict with other existing meanings. Designs like the crosshatch are appropriate only where no cross-over is mandated, e.g., a contra-flow lane, because such a meaning is commonly given that pattern, e.g., in pedestrian islands. The double line diamond design also carries the diamond symbology throughout the SUL and gives the diamond additional visibility in high traffic areas where mid-lane diamonds are more likely to be covered.

Cell #11: Arterial/Reserved/Non-Reversible/No Physical Separation

The facilities represented in this cell are the arterial version of Cell #1. Figure 50 also gives the information system for this cell.

Note that the advanced sign has been redesigned to account for the deficiencies identified in the field studies.

Cell #2: Freeway/Restricted/Reversible Physically Separated

The signing indicated in Figure 51 is for a basic express lane. Various restrictions may have to be added, i.e., no trucks or buses, etc. If an HOV lane is embedded in the express lane, then Cell #1 signing may be incorporated in the facility.

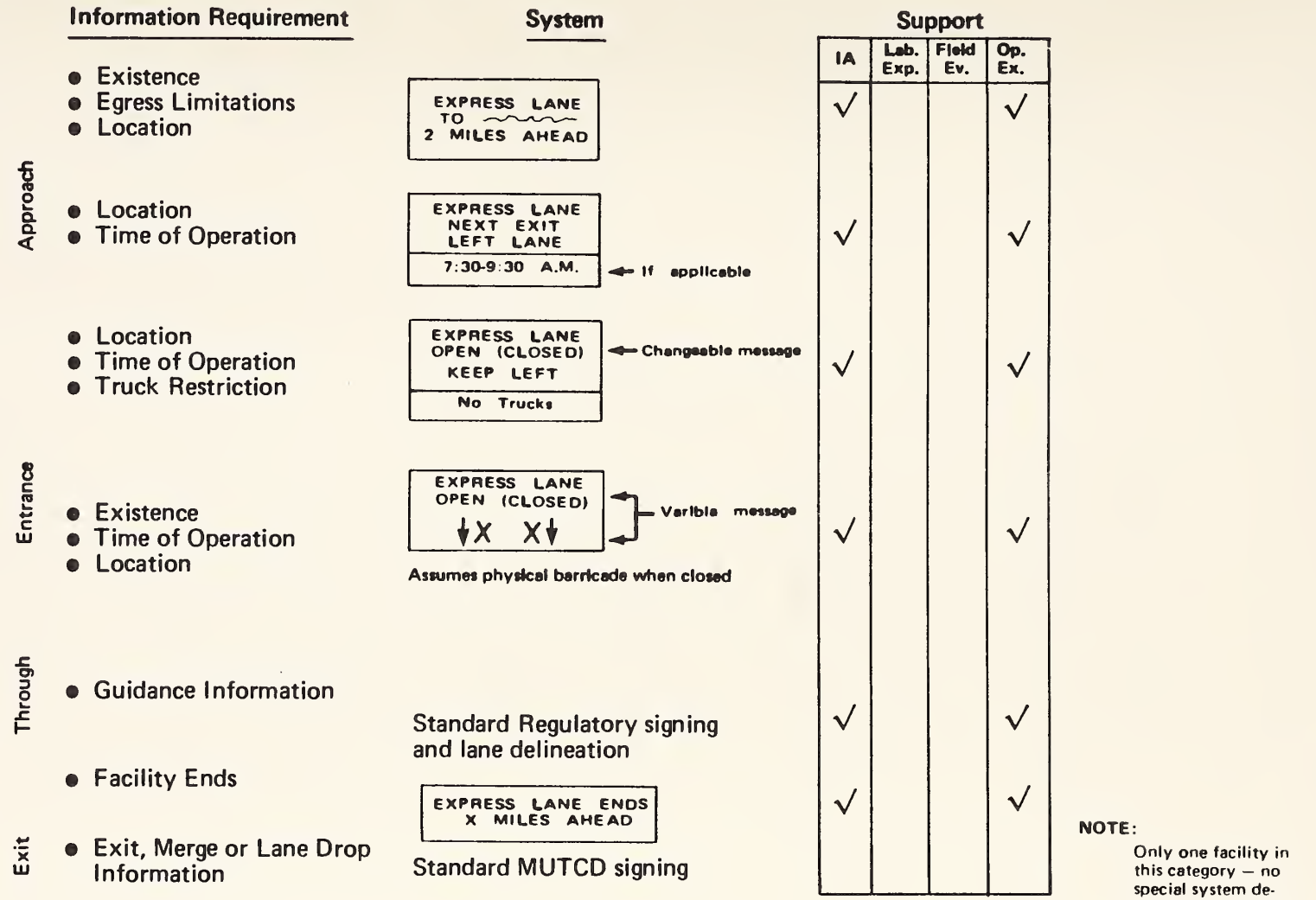


Figure 51. Freeway (Cell #2) reversible lanes.

Cell #12: Arterial/Reserved/Reversible/ No Physical Separation

The only site with this type of operation is the Kalanianaole Highway in Honolulu. Because it is a one-of-a-kind facility, no special signing/delineation system was developed. Should such a system be required, a combination of Cells #11 and #17 signing would meet the information requirements.

Cell #17: Arterial/Reversible/Non-Reserved/No Physical Separation

Reversible lanes are becoming more common as the demand to improve roadway capacity without new construction increases. The real-time lane control signal system found in the MUTCD has an empirical base,* but is not universally applied. For long reversible facilities, lane control signals become expensive to install and maintain. When these SULs go through residential or parkland areas, aesthetic objections may arise. In addition, there is an operational problem when lane control and traffic signals are interspersed along a roadway. Drivers may attend the lane control signal and not notice or ignore the traffic light. Thus a green arrow occasionally "draws" a driver through a red stop light.

Several solutions are possible for this problem. By increasing the space between a stop light and lane control signal, the likelihood of missing the traffic signal should be reduced. If the lane signal needs to be fairly close to the traffic light, i.e., at the start of the SUL, the first set of green arrows could be operated at lower intensity, thus lowering brightness contrast and conspicuity. Also a polarized lens or shade could be used to block the green arrow from view until the driver is past the signal. In combination with these solutions, the traffic

*Forbes, T.W., Gervais, E., & Allen, T. Effectiveness of symbols for lane control signals. *HRB Bulletin*, 1960, *244*, 16-29.

light lenses could be enlarged, light fixture placement changed slightly, lamp intensity (brightness) increased, additional signal heads installed, and WATCH FOR SIGNALS AHEAD signs installed before the intersection.

Because overhead lane control signals are not always feasible, fixed signing is used operationally. In laboratory studies (Volume II) in-use and various alternatives were tested, but they performed so inadequately that they are not recommended.

Similarly a need was identified for signing on cross streets to notify turning drivers of which lane they can use. Of the designs tested, none performed satisfactorily. Rather than suggest an inadequate sign, the information need is left unmet at this time.

The suggested information system is depicted in Figure 52. The only change from the current MUTCD specification is the addition of an advance sign.

Cell #3: Freeway/Reserved/Contra-Flow

Several assumptions that impact on the signing and delineation systems are noted. First, only buses currently use contra-flow lanes. While there has been discussion of allowing a wider user population, the assumption was made that only registered or permitted van pools might become qualified users in the future. Drivers of such vehicles can be given specific instructions on the use of the contra-flow lane at the time of registration and at renewal times.

Second, because contra-flow lanes are intended for designated drivers only and the hazard associated with errant drivers unwittingly entering a contra-flow lane analytically appears

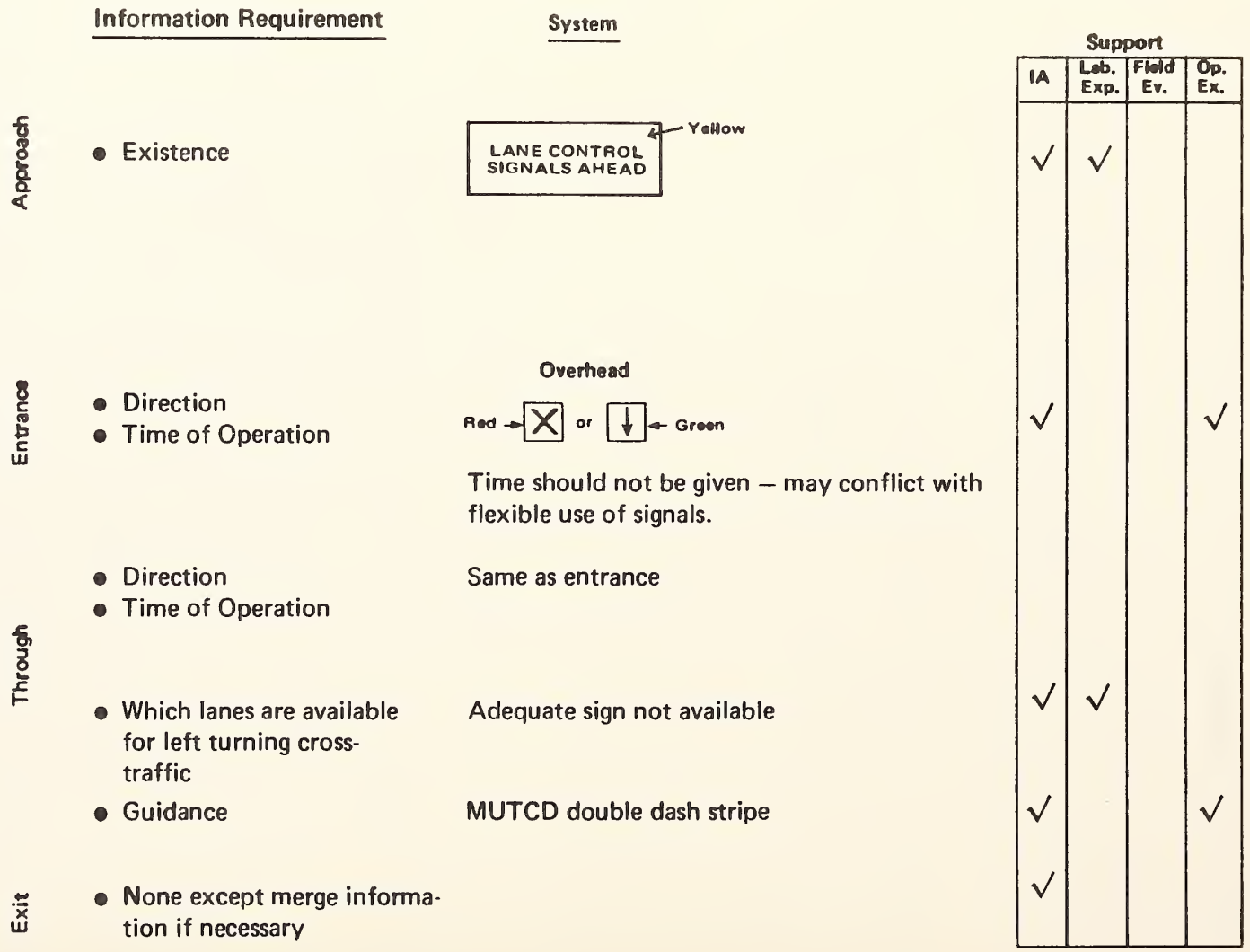


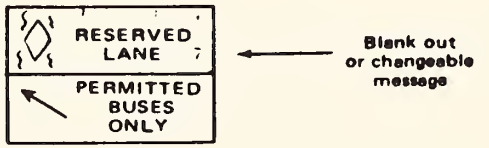
Figure 52. Arterial (Cell #17) reversible lanes.

high, this type of SUL should be relatively obscure. On-site observations at one site found two drivers going into and continuing through, one driver entering and backing out, and several drivers swerving to avoid entering the contra-flow lane; this within a 30-minute filming session.

Third, there has been consideration given to not using post cones to continuously separate the contra-flow from opposing traffic. Regardless of how powerful the signing used, there is a need for continuous delineation of the opposing traffic lanes. This delineation must be obvious and present when the contra-flow is operating, and should not be present during concurrent flow operation. This is important in maintaining the credibility of the delineation treatment. If the treatment is always present but is applicable only part-time, it will tend to be ignored. Therefore, some form of changeable delineation system is required. While placement and removal of post cones is expensive, other alternatives, e.g., barricades rising out of the pavement, are far more expensive.

Finally, the use of a barrier lane or no barrier lane depends on the possibility of drivers straying into the opposing traffic lane. Roadway geometrics apparently affect such probabilities. Where extensive curvature is encountered for a contra-flow lane, a barrier lane appears advisable. Steep up or downgrades subject to considerable icing or snow might also be candidates for barrier lane operation. Long stretches of contra-flow where a breakdown, emergency, or stopping lane is deemed necessary may require use of a barrier lane when shoulder space is unavailable. Relatively straight sections of contra-flow can be operated without a barrier lane with no apparent impact on safety.

Given the above assumptions and considerations, a suggested signing system is shown in Figure 53. The information requirements for drivers traveling "against" the contra-flow lane

Information Requirements	System	Support: IA	Lab. Exp.	Field Ev.	Op. Ex.
	For buses				
Approach: • Existence • Vehicle Restriction • Rules of Use • Location	For buses / vanpools this information is provided through driver training and permitting	✓			✓
• Time of Operation		✓			✓
Entrance: • Vehicle Restrictions • Time of Operation • Location		✓			✓
• Rules of Use	Given to bus drivers plus standard regulatory signs covering speed, lights on, etc.	✓			✓
Through: • Location • Rules of Use	Post cones and standard regulatory signs	✓			✓
Exit: • End of SUL • Exit Procedure	MUTCD merge, yield signing	✓			✓

"Other direction" lanes closed via standard lane drop signing.

Figure 53. Freeway (Cell #3) contra-flow lanes.

direction can be readily met with MUTCD specified signing. No new or SUL specific signs appear necessary. Basically, standard lane closure, repeated "two-way traffic" signs, and lane end techniques can be used.

Delineation at the gore or entrance of the contra-flow lane is not depicted. Delineation, whether through paint, movable cones/Type II barricades, or other movable barriers, clearly must not lure drivers into the SUL. Geometric design is also an important factor in a relatively obscure entrance. Normal traffic should flow past the entrance, and should not have to avoid the entrance. Delineation should positively guide the driver by the contra-flow lane entrance. However, some delineation must be given to the contra-flow users to show them where to enter the lane.

Figure 53 depicts a suggested information system. Because contra-flow sites are unique in terms of geometrics and operation, considerable adaptation, particularly of the approach and entrance signing and delineation, is required. The final installation should be immediately evaluated in terms of "violator" behavior. This means observing the SUL entrance via manual, film, or video-tape methods for several days spread over several weeks. Behavior should be coded for weaves near the entrance by users and non-users, and non-users entering the lane and their subsequent behavior, i.e., continue, stop, back up.

Cell #13: Arterial/Reserved/Contra-Flow

Arterial contra-flow bus lane SULs all currently operate full time in one lane and in a direction to make the street operate like a two-way street, albeit with a disproportionate number of lanes in each direction. Typically these streets are signed as one-way facilities and this is not totally true since

buses are coming from an opposing direction. This is a problem for traffic (vehicular and pedestrian) crossing the SUL.

Signing is intended to keep non-users out of the lane. Bus drivers receive special instruction and training to know where the SUL is and who can use it. The major purpose of signing is to keep the non-user out of the contra-flow lane at entrances, exits, and all along the facility. Delineation is particularly important for identifying the contra-flow lane along the facility.

Cross traffic at non-signalized intersections, including busy driveways and alleys, must be alerted to the two-way nature of the street even though they can only turn in one direction. Pedestrian traffic must also be alerted to the two-way traffic.

Figure 54 depicts the signing and delineation system suggested for arterial contra-flow lanes. The pedestrian sign shown is the one tested in the field evaluations; other configurations and messages may be more suitable for signalized intersections.

Cell #4: Freeway/Reserved/Shoulder/ No Physical Separation

The constraints currently placed on new freeway construction suggest that using shoulders to increase capacity may be a necessity in the near future. For this reason, a signing system is presented here. No adequate field test site existed, so the final information system is based on information requirements and operational experience only.

The problem of providing differing information at different times of the day is again apparent for this type of facility. A problem unique to the reserved shoulder situation is cross traffic

	Information Requirements	System	Support			
			IA	Lab. Exp.	Field Ev.	Op. Ex.
APPROACH	• Existence		√			√
	• Vehicle Restriction		√			√
ENTRANCE	• Location	Indicated by overhead and/or double side mounted signs. Diamond and buses only on pavement.	√			√
	• Rules of use	Standard regulatory signing along SUL and bus driver training.	√			√
THROUGH	With flow of SUL –					
	• Clear definition of SUL	Provided by solid double yellow line, post cones, or buffer zone	√	√		√
	• Warning about cross-traffic/pedestrians	Driver training and standard MUTCD				
	Against flow of SUL –					
	• Location	Provided by solid double yellow line, post cones or buffer zone	√	√		√
	• Existence of traffic in opposite direction	ALSO PRESENCE OF BUSES IS A POSITIVE INFORMATION SOURCE				
	Across flow of SUL –					
	• Existence of traffic in two directions					
	• Turn Restrictions	Standard MUTCD verbal or symbolic MUTCD signing				
EXIT	Pedestrians					
	• Existence of two-way traffic	Same as above plus	√		√	
		Plus message printed on sidewalk or street near curb.	√			√
	• End of facility	Depends on geometrics of SUL – standard MUTCD signing, e.g., RESUME TWO-WAY TRAFFIC or ONE-WAY ROAD may suffice.	√			√

Figure 54. Arterial (Cell #13) contra-flow lanes.

entering and exiting the freeway. Where a shoulder next to the median is used, the problem is minimal, but is replaced with difficulty in providing emergency/enforcement pull-off space. Another type of information that must be clearly provided is the "do not stop or park on the shoulder" when operating as an SUL.

The information system shown in Figures 55 and 56 is adapted from the Cell #1 signing. Whenever possible, similar signing is being developed so that standardization will be possible. This should contribute to creating an expectancy in drivers that will be valid across restricted SULs as well as to ease of understanding and implementation. Variable message signing could well solve the problem of which role a shoulder is playing and, though expensive, is worthy of consideration.

For an SUL facility operating as a non-reserved shoulder for through traffic during peak hours, a simple version of Cell #4 provides the signing system.

Cell #14: Arterial/Shoulder/Reserved/
Non-Reversible/No Physical Separation

There is only one arterial shoulder SUL facility in existence; however, the discussion and rationale for creating freeway shoulder SUL signing applies equally to the arterial situation.

The information requirements for this facility are the same as those found in Cell #11. The only addition is the no parking or stopping requirement during operating hours. A combination of the Cell #11 and Cell #4 signing meets these information requirements, and no new signing needs to be generated.

There is a particular danger for cross traffic, however. If there is not very clear sight distance in both directions from a

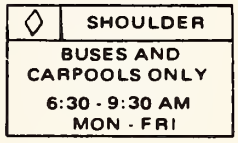
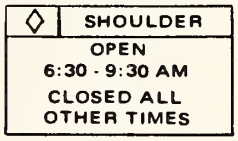
	Information Requirement	Signing System A
Approach	• Existence	1.
Approach	• Location • Type of Restriction • Time of Operation	2. 
Entrance	• Location • Type of Restriction • Time of Operation	Same as approach 3. 
Through	• Location • Type of restriction • Time of operation	Same as approach
Through	• Use SUL for exit lane	4.
Through	• Repeat entrance information at entrance ramps	Use signs 1 and 2 on ramp
	(See Figure 8 for sign placement diagram)	
Exit	• End of facility	
Exit	• How to exit	Standard MUTCD merge or lane drop signing

Figure 55. Signing systems for Cell #4.

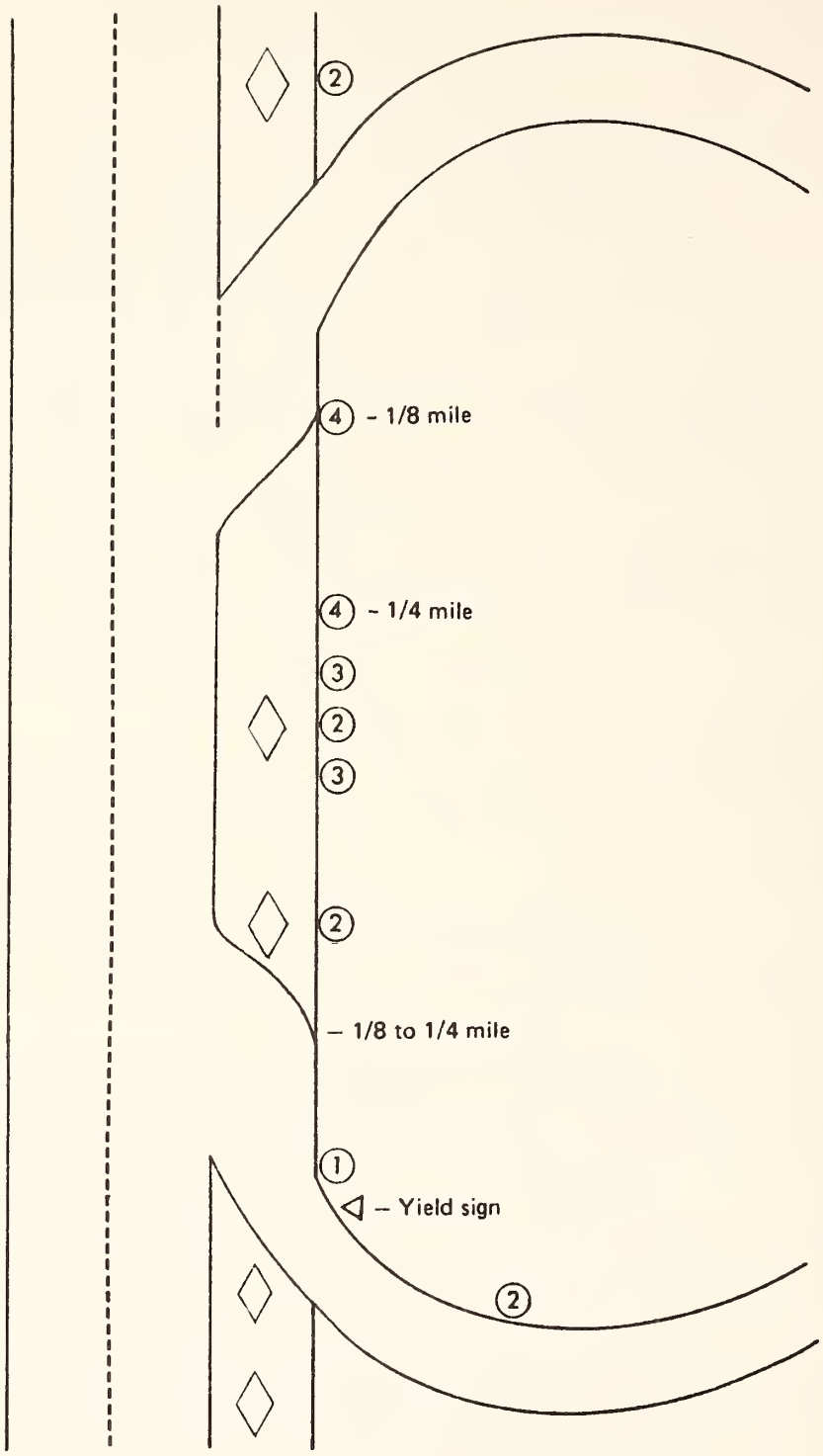


Figure 56. SUL sign placement at exit and entrance ramps–Cell #4 facilities.

stop line before the shoulder begins, entering drivers will tend to stop with part (or all) of their vehicle on the shoulder. The hazard to HOVs is obvious. This same situation applies to cross streets, driveways, and parking lot entrances. If clear sight distance is not possible, some type of sign warning that through buses use the shoulder is necessary, as shown below.

CHAPTER 10
ADDITIONAL QUESTIONS

As with most research, this project has a few loose ends that can only be resolved through additional research. None of these issues imply that a particular type of SUL should not be implemented; however, they are issues that could improve the suggested signing systems.

1. The problem of weaving in and out of concurrent flow freeway HOV lanes across several lanes of general traffic could not be adequately addressed at the test sites. The magnitude of this problem in terms of accidents/near misses and traffic flow effects is not clear. Therefore, the impact that signing could have, if any, on the problem is unclear. Additional sites where this phenomena could be examined in more detail, and necessary counter-measures tested, may become available in the future so that such a study could be conducted.

2. If shoulder SULs are going to be implemented more extensively, the signing system suggested in Chapter 9 should be field evaluated.

3. If arterial shoulder SULs are to be implemented, the cross traffic signing message and placement should be empirically tested and field evaluated. Also specific site distance requirements for cross traffic at intersections, driveways, etc. should be considered.

4. The SUL signing along concurrent flow arterial lanes, particularly shoulder mounted, is still not sufficiently noticed. While public relations or educational campaigns were recommended to improve this situation, additional study of conspicuity, enhancing features such as color may be worth field testing.

5. The buffer zone as developed in this project is relatively novel. It was tested at three sites. While including the buffer zone in information systems was suggested, evaluation of the concept as it is used on other facilities is encouraged.

APPENDIX A

RATIONALE FOR NOT USING CERTAIN SUL CATEGORIES IN THE FIELD TESTS

Additional explanation about the reasons other cells were not selected is provided here. Cell numbers refer to Figure 1 of this volume.

Cell #2, Reversible/Reserved Freeway

The physical separation on these facilities eliminates weaving problems and minimal through information is required. The advance, entrance, and exit signing conformed to the information requirements and various media are currently used (e.g., static, variable message). The problems identified were associated with unique geometric characteristics of one facility and were more amenable to an enforcement countermeasure. The limited number of sites, little or no need to modify signing or provide additional information, and apparent small interest in building similar facilities dictated the non-selection decision.

Cell #3, Freeway Contra-Flow Lanes

Only three facilities of this type currently operate in the U.S. The Long Island Expressway has a state-of-the-art variable message signing system. It was difficult to think of information that could be added. Interstate N.J. 495 leading to the Lincoln Tunnel is unique, with exclusive entry ramps for buses and such heavy bus volume that no operational effects could be changed by different signing or marking. U.S. 101 from the Golden Gate Bridge north into Marin County, California, had one major problem--signing at the gore and entrance to the contra-flow lane. Since our initial visits, that sign has been modified. There were no

other information system deficiencies. In summary, none of the sites could support an evaluation in terms of measurable behaviors (e.g., weaving, violations), there could be no control site, and each facility is unique enough to make generalizations to other situations suspect.

Cell #4, Shoulder Used as SUL During Peak

Only two such facilities exist. The BQE on Long Island is a unique left shoulder operation. The marking scheme and the situation are one-of-a-kind. The right shoulder SUL, Seattle 520, appeared to represent a very useful technique for increasing bus/carpool throughput during peak hours without removing general lane capacity. BioTechnology considered the site as a candidate for field testing. Preliminary violator and weaving data indicated an evaluation could be supported, particularly at the ramp entrance that cut across the shoulder SUL. The State of Washington decided to remove the toll barriers just after the SUL ended, and to restripe the SUL to be a lane merge instead of an exit into a toll plaza. Several weeks after that was completed, we again collected data at the site. The toll booth removal and restriping resulted in extensive queuing and delays--the merge from the SUL was not functioning well. To alleviate the situation, state engineers planned to shorten the SUL, stopping it at the ramp entrance point. Given the new problems and extensive changes, the site could only present confounded data and limited opportunity to test new signs/markings. Therefore, a Seattle 520 site was abandoned as a candidate for field work.

Cell #12, Reversible Reserved Arterial Lane

The one left lane or inner reversible lane site is very unique, and any field testing here would not be useful on other facilities. Therefore, it was not given a high priority.

Cell #14, Arterial Shoulder Used as SUL During Peak Hours

This is another idea to economically increase HOV throughput during peak hours without reducing general lane capacity. The one facility in the category had low bus volume, low violation rates, and a rather complete information system. The primary problem identified in the information analysis was warning cross street motorists to look for traffic on the shoulder lane. Associated with this was a need to provide adequate sight distance at the stop sign/light so cross traffic would not be sticking out onto the SUL. This would have been difficult to test on the Seattle facility since considerable construction, tree removal, etc. would have been required--activities beyond the scope of project resources. Also, the amount of cross traffic was relatively small at individual streets, so multiple testing would have been needed. Therefore, this cell received a relatively low priority, because the expenditure to test this particular treatment on a one-of-a-kind facility would be substantial.

Cell #17, Arterial Reversible Lanes

The existing through signing/marking system (lane control signals/double yellow dashes) was found adequate in the information analysis. Advance warning information was always lacking. Various signs were studied in Task 2 of this project, and one was recommended. Given the minimal impact expected from this sign in terms of observable driving behavior, a field test for this cell was given a lower priority.

APPENDIX B

ROUTE AND DEBRIEFING MATERIALS USED FOR THE DRIVE-THROUGH STUDY - BALTIMORE

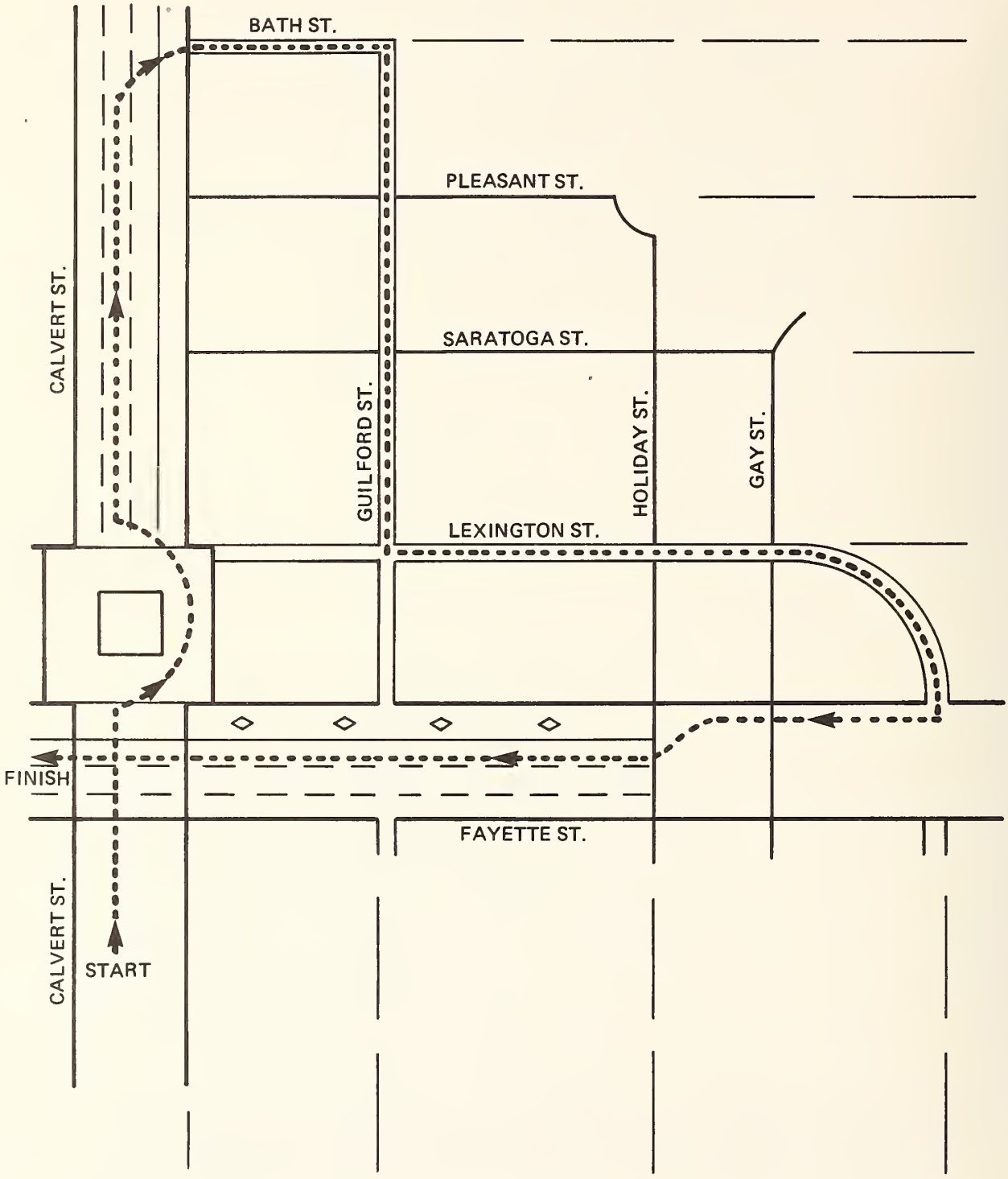
The contents of this appendix, in order of appearance, are:

- Maps of Routes A (Fayette and Calvert Streets) and B (Charles and Calvert Streets
- The debriefing form used by the experimenter
- Pictures used with questions 14-24*
- Pictures used with questions 25-30.

*Sign C shows the split presentation treatment (Route B). Subjects on Route A saw a picture of the single sign treatment as Sign C.

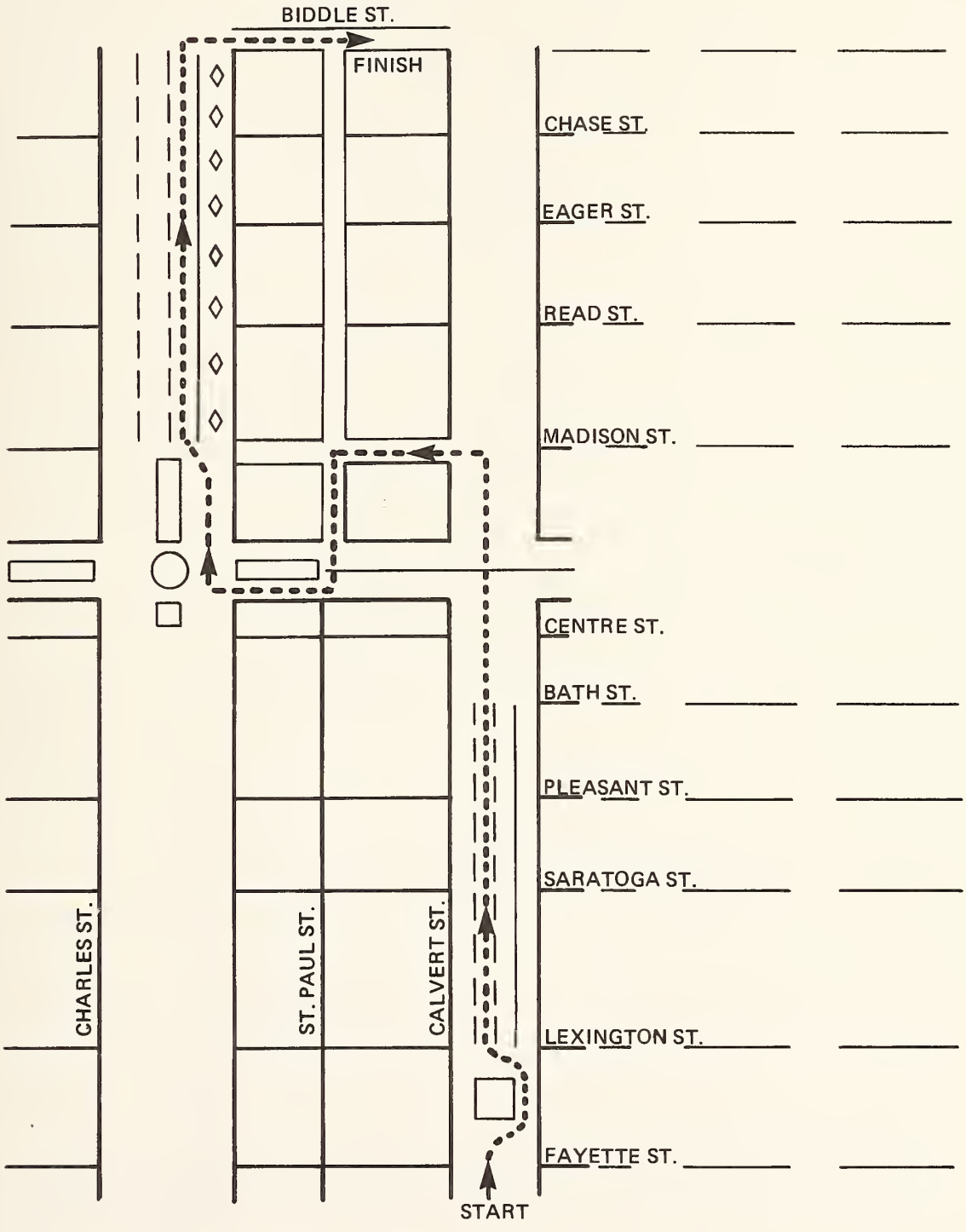
SIGNING AND DELINEATION FIELD SURVEY
FOR SPECIAL USE LANES

ROUTE LOG



SIGNING AND DELINEATION FIELD SURVEY FOR SPECIAL USE LANES

ROUTE LOG



1. Subject ID # ☐☐☐

2. Interviewer # ☐☐

3. Date _____ ☐☐☐

36. Time Out ☐☐☐☐

4. Route ☐

5. User Code ☐☐

6. How often do you drive around here? (Show map)

1 ☐ This is the first time

2 ☐ Once or twice before

3 ☐ About once or twice a month

4 ☐ About once or twice a week

5 ☐ About once a day

6 ☐ More than once a day

☐

7. Sex ☐ M=1 ☐ F=2

8. Age ☐☐ 1 = 16-18 2 = 18.1-20 3 = 20.1-40 4 = 40.1-59 5 = 60+

9. How many years have you been a licensed driver? ☐☐ 1 = 1 2 = 1.1-5 3 = 5.1-10 4 = 10.1-20 5 = > 20.1

---

10. Did you notice any information about the use of the right lane on any of the streets just traveled?

☐ Yes/Go to 11 (1)

☐ No/Go to 13 (2)

11. What did you notice and where?

☐ SUL operation/Go to 12 (1-8) _____

☐ Non-SUL referent/Go to 13 (9) _____

12. Could you give me details of the bus lane operation, i.e., who can use it and when?

☐

_____

_____ /Go to 14

13. How about Calvert or Route A — Fayette / Route B — Charles Sts.?

☐ Yes: SUL Referent (1) _____ Go to 12

☐ No/Go to 14 (2)

14. Which of these signs did you notice on today's drive?
(Show photo set #1)

37 ☐ A Go to 15

38 ☐ B Go to 17

39 ☐ C Go to 19

40 ☐ D Go to 21

41 ☐ E Go to 21

42 ☐ F Go to 21

43 ☐ G Go to 21

44 ☐ None — Go to 21

15. What did this sign mean to you? (A)

1 ☐ I can use this lane
2 ☐ I can not use this lane
3 ☐ Bus only lane
4 ☐ Shoulder lane
5 ☐ Breakdown lane
6 ☐ No meaning
7 ☐ Other ☐ _____

16. On a scale of 1 being uncertain, to 5 being very certain, how sure are you of this meaning?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

17. What did this sign mean to you? (B)

1 ☐ I can use this lane
2 ☐ I can not use this lane
3 ☐ Bus only lane
4 ☐ Shoulder lane
5 ☐ Breakdown lane
6 ☐ No meaning
7 ☐ Other ☐ _____

18. On a scale of 1 being uncertain, to 5 being very certain, how sure are you of this meaning?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

19. What did this sign mean to you? (C)

1 ☐ I can use this lane
2 ☐ I can not use this lane
3 ☐ Bus only lane
4 ☐ Shoulder lane
5 ☐ Breakdown lane
6 ☐ No meaning
7 ☐ Other ☐ _____

20. On a scale of 1 being uncertain, to 5 being very certain, how sure are you of this meaning?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

21. This sign was out on Route A — Fayette St. / Route B — Charles St. (B)
What does it mean to you?

1 ☐ I can use this lane
2 ☐ I can not use this lane
3 ☐ Bus only lane
4 ☐ Shoulder lane
5 ☐ Breakdown lane
6 ☐ No meaning
7 ☐ Other ☐ _____

22. On a scale of 1 being uncertain, to 5 being very certain, how sure are you of this meaning?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

23. This sign was out on Route A — Fayette St. / Route B — Charles St. (C)

24. On a scale of 1 being uncertain, to 5 being very certain, how sure are you of this meaning?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

25. We are interested in your reactions to certain street markings along your drive at Route A — Fayette St. / Route B — Charles St.
Which of these roadway markings did you notice on todays drive? (Show photo set #2)

45 ☐ A Go to 28
46 ☐ B Go to 28
47 ☐ C Go to 26
48 ☐ D Go to 28
49 ☐ None

26. What meaning did this marking convey to you? (C)

1 ☐ I can use this lane
2 ☐ I can not use this lane
3 ☐ Bus only lane
4 ☐ Shoulder lane
5 ☐ Breakdown lane
6 ☐ No meaning
7 ☐ Other ☐ _____

27. On a scale of 1 being uncertain, to 5 being very certain, how sure are you of this meaning?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

28. This marking was out on Route A — Fayette St. / Route B — Charles St.
What does it mean to you?

1 ☐ I can use this lane
2 ☐ I can not use this lane
3 ☐ Bus only lane
4 ☐ Shoulder lane
5 ☐ Breakdown lane
6 ☐ No meaning
7 ☐ Other ☐ _____

29. On a scale of 1 being uncertain, to 5 being very certain, how sure are you of this meaning?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

30. In your opinion, which of the above noted signs and markings best conveyed information which you need about the reserved bus lane?

Sign: 37 ☐ A 38 ☐ B 39 ☐ C 40 ☐ D 41 ☐ E 42 ☐ F 43 ☐ G

Marking: ☐ A (45) ☐ B (46) ☐ C (47) ☐ D (48)

31. How might the signs and markings be modified to be more effective?

_____

_____

_____

If subject was peak violator — to to questions 32-35. If not, return for thanks, payment and dismissal.

Violator Supplement

32. Do you think that a reserved lane for buses is a good idea?

50 ☐ Yes — it's a good idea
51 ☐ Yes — If it worked properly (i.e., buses stayed in — cars stayed out)
52 ☐ Yes — If it were enforced more
53 ☐ Yes — If it operated during rush hour only
54 ☐ I don't know
55 ☐ I really don't understand the idea
56 ☐ I just don't really care one way or the other
57 ☐ No — I don't like the idea at all
58 ☐ No — It creates more traffic congestion
59 ☐ No — Buses don't really need it

33. Under what conditions will you use this special bus lane?

1 ☐ Delay in general traffic lanes — stop and go or queues

2 ☐ I need to pass slow moving traffic

3 ☐ I'm just generally in a hurry

4 ☐ If there is no apparent enforcement/if I think I can get away with it

5 ☐ Emergency or unusual circumstances and speed is critical

6 ☐ Other people violating lane

7 ☐ Other _____

34. Please show me using this scale (show card) how important making time is to you (circle response)

VI	I	SI	SU	U	VU
1	2	3	4	5	6

35. On this next scale, (show card) please show me how frequently you think drivers violate the special bus lane

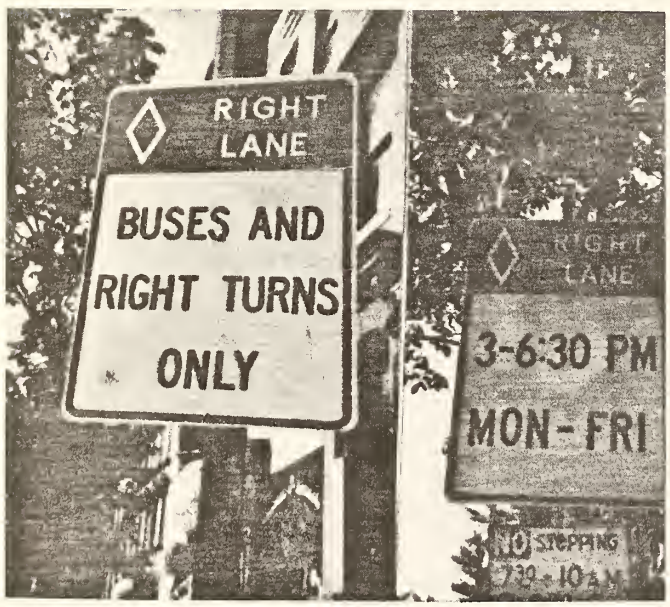
5%	10%	20%	40%	60%	80%
1	2	3	4	5	6

CURB LANE
RIGHT TURNS &
BUSES
ONLY
7 - 9 AM
4 - 6 PM

A

RESTRICTED
RIGHT LANE
AHEAD

B


RIGHT
LANE
BUSES AND
RIGHT TURNS
ONLY
RIGHT
LANE
3-6:30 PM
MON-FRI
NO STOPPING
7:30 - 10 A.M.

C

BUSES
AND RIGHT TURNS
ONLY
7-9
AM
4-6
AM

D

CURBLANE
BUSES ONLY
EXCEPT RIGHT TURNS
4-6PM

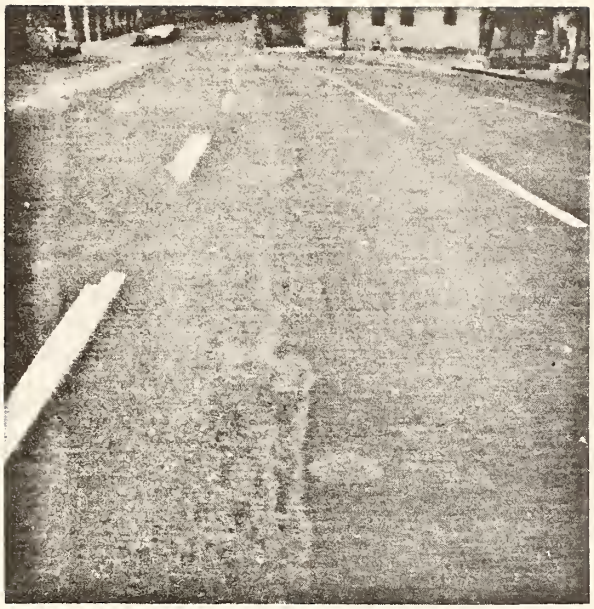
E

SNOW
EMERGENCY
ROUTE
NO PARKING
DURING EMERGENCY
VEHICLES TOWED
AWAY

F

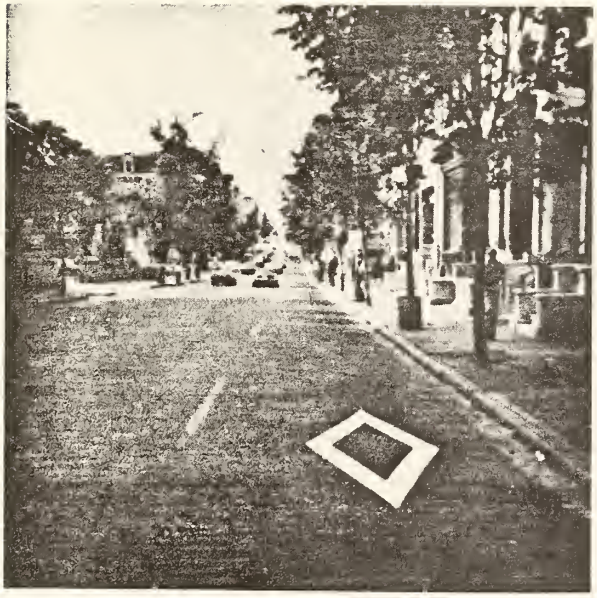
NO STOPPING
7:30 - 10 A.M.
3-6:30 P.M.
NO PARKIN
EXCEPT SUN
CARS TOWED AWAY

G

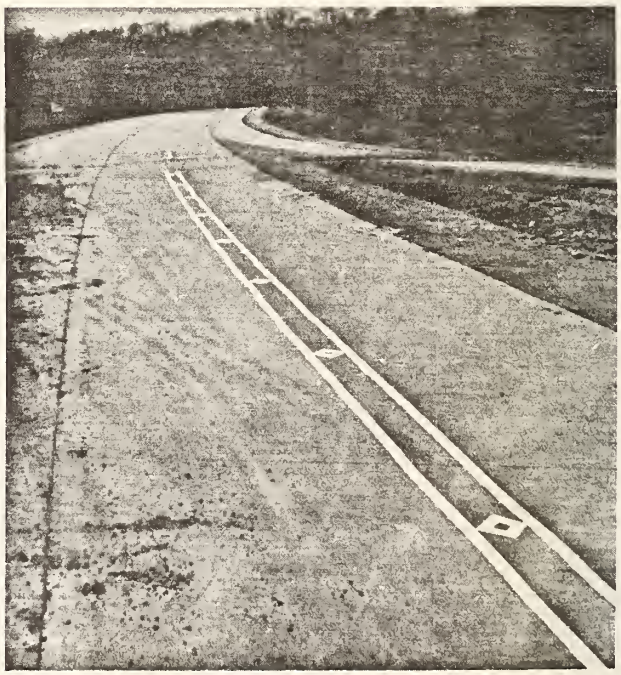


A

B



C



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APPENDIX C

DETAILED QUESTIONNAIRE DATA
(SAN FRANCISCO)

Before Questions

1. Are you aware of a special use for any lane on this street during rush hour?

		Yes	No	Total
E[1]	Violator[2]	56/76.7%	17/23.3%	73
	Through	70/62.5%	42/37.5%	112
C	Violator	30/70%	10/25%	40
	Through	63/61%	40/39%	103
				328

2a. (For those answering YES to Q1) Which lane is it and who can use it?

		Correct	Incorrect	Total
E	Violator	55	0	55
	Through	69	1	70
	Violator	29	0	29
	Through	63	0	63
				217

2b. (For those answering NO to Q1) About how often do you drive by here?

	Every Day	At Least Once per Week	Less Than Once per Week	Total
Through	27/32%	20/24%	37/44%	84/100%
Violator	4/17%	7/29%	13/54%	24/100%

[1]E = Experimental streets; C = Control streets.

[2]Violator = driver illegally in the SUL; Through = driver in any of the general, through traffic lanes.

3. Do you think the special bus lane is a good idea? (For those answering YES to Q1)
The right lane is for buses and right turns only. Do you think this is a good idea? (For those answering NO to Q1)

		Yes	No	Undecided
E	Violator	32/43.8%	30/41.1%	11/15.1%
	Through	68/56.7%	46/83.3%	6/ 5%
C	Violator	23/53.3%	15/35%	3/11.5%
	Through	61/60.7%	35/34.6%	5/ 5%

After Questions

1. Did you see any information about the use of the right lane on this street?

		Yes	No	Total
E	Violator	74/49%	77/51%	151/100%
	Through	129/40.2%	192/59.8%	321/100%
C	Violator	27/41.5%	31/53.5%	58/100%
	Through	46/27%	124/73%	170/100%
	E	203/43%	269/57%	472/100%
	C	73/32%	155/68%	228/100%

$x^2 = 7.32$, 1 df
$p < .01$

2&3. What did you see? (For those answering YES to Q1); What did they tell you? Did you see these signs and markings? (show photo) (For those answering NO to Q1); What did they tell you?

		Correct ID of Bus Lane	Did Not See Or Misunderstood	Total
E	Violator	42/67.7%	20/32.3%	42/100%
	Through	24/47%	27/53%	51/100%
C	Violator	25/86.2%	4/13.8%	29/100%
	Through	18/66.7%	9/33.3%	27/100%
	E	66/58%	47/42%	113/100%
	C	43/77%	13/33%	56/100%

$x^2 = 4.75$, 1 df

$p > .02$*

*.01 was selected as the probability level for significance in the field studies; therefore, 4.75 with 1 df is not significant.

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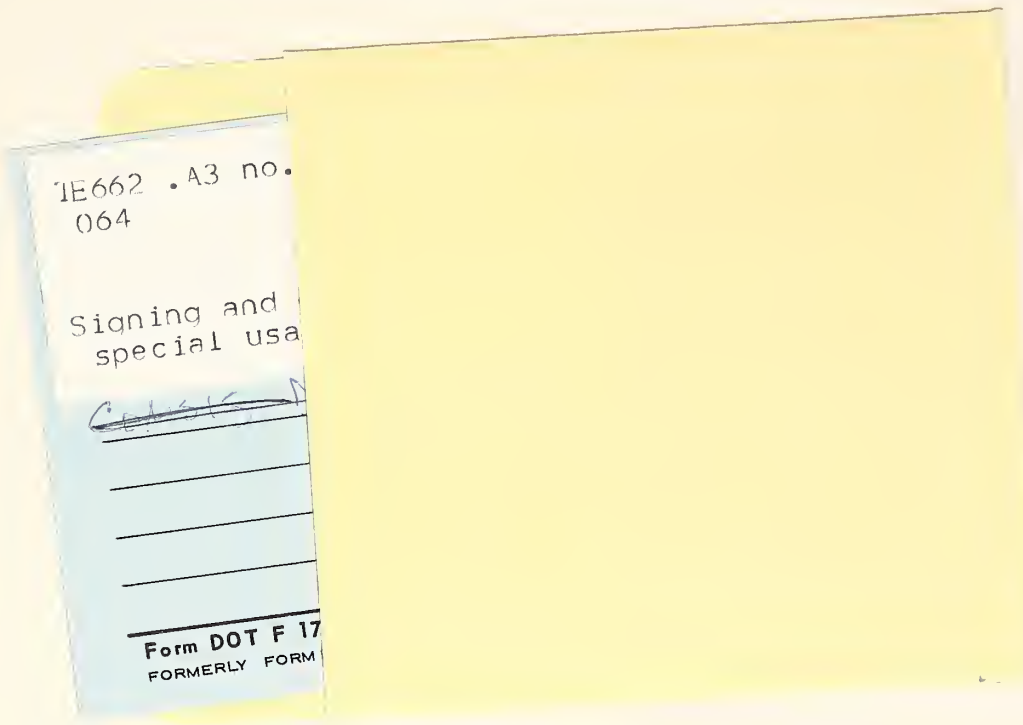
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FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

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This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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